

# Package ‘network’

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**Description** Tools to create and modify network objects. The network class can represent a range of relational data types, and supports arbitrary vertex/edge/graph attributes.

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## Description

Tools to create and modify network objects. The network class can represent a range of relational data types, and supports arbitrary vertex/edge/graph attributes.

## Details

The network package provides tools for creation, access, and modification of network class objects. These objects allow for the representation of more complex structures than can be readily handled by other means (e.g., adjacency matrices), and are substantially more efficient in handling large, sparse networks. While the full capabilities of the network class can only be exploited by means of the various custom interface methods (see below), many simple tasks are streamlined through the use of operator overloading; in particular, network objects can often be treated as if they were adjacency matrices (a representation which will be familiar to users of the sna package). network objects are compatible with the sna package, and are required for many packages in the statnet bundle.

Basic information on the creation of network objects can be found by typing `help(network)`. To learn about setting, modifying, or deleting network, vertex, or edge attributes, see `help(attribute.methods)`. For information on custom network operators, type `help(network.operators)`; information on overloaded operators can be found via `help(network.extraction)`. Additional help topics are listed below.

```
Package:  network
Version:  1.14
Date:     May 7, 2016
Depends:  R (>= 2.10), utils
Suggests: sna, statnet.common (>= 3.1-0)
License:  GPL (>=2)
```

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<code>which.matrix.type</code>	Heuristic Determination of Matrix Types for Network Storage

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---

add.edges

*Add Edges to a Network Object*


---

**Description**

Add one or more edges to an existing network object.

**Usage**

```
add.edge(
  x,
  tail,
  head,
  names.eval = NULL,
  vals.eval = NULL,
  edge.check = FALSE,
  ...
)
```

```
add.edges(x, tail, head, names.eval = NULL, vals.eval = NULL, ...)
```

**Arguments**

x	an object of class network
tail	for add.edge, a vector of vertex IDs reflecting the tail set for the edge to be added; for add.edges, a list of such vectors
head	for add.edge, a vector of vertex IDs reflecting the head set for the edge to be added; for add.edges, a list of such vectors
names.eval	for add.edge, an optional list of names for edge attributes; for add.edges, a list of length equal to the number of edges, with each element containing a list of names for the attributes of the corresponding edge
vals.eval	for add.edge, an optional list of edge attribute values (matching names.eval); for add.edges, a list of such lists
edge.check	logical; should we perform (computationally expensive) tests to check for the legality of submitted edges?
...	additional arguments

**Details**

The edge checking procedure is very slow, but should always be employed when debugging; without it, one cannot guarantee that the network state is consistent with network level variables (see [network.indicators](#)). For example, by default it is possible to add multiple edges to a pair of vertices.

Edges can also be added/removed via the extraction/replacement operators. See the associated man page for details.

**Value**

Invisibly, `add.edge` and `add.edges` return pointers to their modified arguments; both functions modify their arguments in place..

**Note**

`add.edges` and `add.edge` were converted to an S3 generic functions in version 1.9, so they actually call `add.edges.network` and `add.edge.network` by default, and may call other versions depending on context (i.e. when called with a `networkDynamic` object).

**Author(s)**

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**References**

Butts, C. T. (2008). "network: a Package for Managing Relational Data in R." *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

**See Also**

[network](#), [add.vertices](#), [network.extraction](#), [delete.edges](#), [network.edgelist](#)

**Examples**

```
#Initialize a small, empty network
g<-network.initialize(3)

#Add an edge
add.edge(g,1,2)
g

#Can also add edges using the extraction/replacement operators
#note that replacement operators are much slower than add.edges()
g[,3]<-1
g[,]

#Add multiple edges with attributes to a network

# pretend we just loaded in this data.frame from a file
# Note: network.edgelist() may be simpler for this case
e1Data<-data.frame(
  from_id=c("1","2","3","1","3","1","2"),
  to_id=c("1", "1", "1", "2", "2", "3", "3"),
  myEdgeWeight=c(1, 2, 1, 2, 5, 3, 9.5),
  someLetters=c("B", "W", "L", "Z", "P", "Q", "E"),
  edgeCols=c("red","green","blue","orange","pink","brown","gray"),
  stringsAsFactors=FALSE
)
```

```
valueNet<-network.initialize(3,loops=TRUE)

add.edges(valueNet,e1Data[,1],e1Data[,2],
          names.eval=rep(list(list("myEdgeWeight","someLetters","edgeCols")),nrow(e1Data)),
          vals.eval=lapply(1:nrow(e1Data),function(r){as.list(e1Data[r,3:5])}))

list.edge.attributes(valueNet)
```

---

add.vertices                      *Add Vertices to an Existing Network*

---

### Description

add.vertices adds a specified number of vertices to an existing network; if desired, attributes for the new vertices may be specified as well.

### Usage

```
add.vertices(x, nv, vattr = NULL, last.mode = TRUE, ...)
```

### Arguments

x	an object of class network
nv	the number of vertices to add
vattr	optionally, a list of attributes with one entry per new vertex
last.mode	logical; should the new vertices be added to the last (rather than the first) mode of a bipartite network?
...	possible additional arguments to add.vertices

### Details

New vertices are generally appended to the end of the network (i.e., their vertex IDs begin with `network.size(x)` an count upward). The one exception to this rule is when `x` is bipartite and `last.mode==FALSE`. In this case, new vertices are added to the end of the first mode, with existing second-mode vertices being permuted upward in ID. (`x`'s `bipartite` attribute is adjusted accordingly.)

Note that the attribute format used here is based on the internal (vertex-wise) storage method, as opposed to the attribute-wise format used by `network`. Specifically, `vattr` should be a list with one entry per new vertex, the `i`th element of which should be a list with an element for every attribute of the `i`th vertex. (If the required `na` attribute is not given, it will be automatically created.)

### Value

Invisibly, a pointer to the updated network object; `add.vertices` modifies its argument in place.

**Note**

add.vertices was converted to an S3 generic function in version 1.9, so it actually calls add.vertices.network by default and may call other versions depending on context (i.e. when called with a networkDynamic object).

**Author(s)**

Carter T. Butts <butts@uci.edu>

**References**

Butts, C. T. (2008). "network: a Package for Managing Relational Data in R." *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

**See Also**

[network](#), [get.vertex.attribute](#), [set.vertex.attribute](#)

**Examples**

```
#Initialize a network object
g<-network.initialize(5)
g

#Add five more vertices
add.vertices(g,5)
g

#Create two more, with attributes
vat<-replicate(2,list(is.added=TRUE,num.added=2),simplify=FALSE)
add.vertices(g,2,vattr=vat)
g%v%"is.added"      #Values are only present for the new cases
g%v%"num.added"

#Add to a bipartite network
bip <-network.initialize(5,bipartite=3)
get.network.attribute(bip,'bipartite') # how many vertices in first mode?
add.vertices(bip,3,last.mode=FALSE)
get.network.attribute(bip,'bipartite')
```

---

as.color

*Transform vector of values into color specification*

---

**Description**

Convenience function to convert a vector of values into a color specification.



**Usage**

```
as.color(x, opacity = 1)
```

```
is.color(x)
```

**Arguments**

**x** vector of numeric, character or factor values to be transformed

**opacity** optional numeric value in the range 0.0 to 1.0 used to specify the opacity/transparency (alpha) of the colors to be returned. 0 means fully opaque, 1 means fully transparent.

Behavior of `as.color` is as follows:

- integer numeric values: unchanged, (assumed to correspond to values of R's active [palette](#))
- integer real values: will be translated to into grayscale values ranging between the max and min
- factor: integer values corresponding to factor levels will be used
- character: if values are valid colors (as determined by `is.color`) they will be returned as is. Otherwise converted to factor and numeric value of factor returned.

The optional `opacity` parameter can be used to make colors partially transparent (as a shortcut for [adjustcolor](#). If used, colors will be returned as hex rgb color string (i.e. "#00FF0080")

The `is.color` function checks if each character element of `x` appears to be a color name by comparing it to [colors](#) and checking if it is an HTML-style hex color code. Note that it will return `FALSE` for integer values.

These functions are used for the color parameters of [plot.network](#).

**Value**

For `as.color`, a vector integer values (corresponding to color palette values) or character color name. For `is.color`, a logical vector indicating if each element of `x` appears to be a color

`as.color()` returns `TRUE` if `x` is a character in a known color format.

**Examples**

```
as.color(1:3)
as.color(c('a', 'b', 'c'))

# add some transparency
as.color(c('red', 'green', 'blue'), 0.5) # gives "#FF000080", "#00FF0080", "#0000FF80"

is.color(c('red', 1, 'foo', NA, '#FFFFFF55'))
```

---

as.data.frame.network *Coerce a Network Object to a data.frame*

---

### Description

The as.data.frame method coerces its input to a data.frame containing x's edges or vertices.

### Usage

```
## S3 method for class 'network'
as.data.frame(
  x,
  ...,
  unit = c("edges", "vertices"),
  na.rm = TRUE,
  attrs_to_ignore = "na"
)
```

### Arguments

x	an object of class network
...	additional arguments
unit	whether a data.frame of edge or vertex attributes should be returned.
na.rm	logical; ignore missing entries when constructing the data frame?
attrs_to_ignore	character; a vector of attribute names to exclude from the returned data.frame (Default: "na")

---

as.edgelist *Convert a network object into a numeric edgelist matrix*

---

### Description

Constructs an edgelist in a sorted format with defined attributes.

### Usage

```
## S3 method for class 'network'
as.edgelist(
  x,
  attrname = NULL,
  as.sna.edgelist = FALSE,
  output = c("matrix", "tibble"),
  ...
)
```

```

)

## S3 method for class 'matrix'
as.edgelist(
  x,
  n,
  directed = TRUE,
  bipartite = FALSE,
  loops = FALSE,
  vnames = seq_len(n),
  ...
)

## S3 method for class 'tbl_df'
as.edgelist(
  x,
  n,
  directed = TRUE,
  bipartite = FALSE,
  loops = FALSE,
  vnames = seq_len(n),
  ...
)

is.edgelist(x)

```

### Arguments

x	a network object with additional class added indicating how it should be dispatched.
attrname	optionally, the name of an edge attribute to use for edge values; may be a vector of names if output="tibble"
as.sna.edgelist	logical; should the edgelist be returned in edgelist form expected by the sna package? Ignored if output="tibble"
output	return type: a <a href="#">matrix</a> or a <a href="#">tibble</a> ; see <a href="#">as.matrix.network</a> for the difference.
...	additional arguments to other methods
n	integer number of vertices in network, value passed to the 'n' flag on edgelist returned
directed	logical; is network directed, value passed to the 'directed' flag on edgelist returned
bipartite	logical or integer; is network bipartite, value passed to the 'bipartite' flag on edgelist returned
loops	logical; are self-loops allowed in network?, value passed to the 'loops' flag on edgelist returned
vnames	vertex names (defaults to vertex ids) to be attached to edgelist for sna package compatibility

## Details

Constructs a edgelist matrix or tibble from a network, sorted tails-major order, with tails first, and, for undirected networks, tail < head. This format is required by some reverse-depending packages (e.g. ergm)

The [as.matrix.network.edgelist](#) provides similar functionality but it does not enforce ordering or set the edgelist class and so should be slightly faster.

is.edgelist tests if an object has the class 'edgelist'

## Value

A matrix in which the first two columns are integers giving the tail (source) and head (target) vertex ids of each edge. The matrix will be given the class edgelist.

The edgelist has additional attributes attached to it:

- `attr("n")` the number of vertices in the original network
- `attr("vnames")` the names of vertices in the original network
- `attr("directed")` logical, was the original network directed
- `attr("bipartite")` was the original network bipartite
- `attr("loops")` does the original network contain self-loops

Note that if the `attrname` attribute is used the resulting edgelist matrix will have three columns. And if `attrname` refers to a character attribute, the resulting edgelist matrix will be character rather than numeric unless `output="tibble"`.

## Note

NOTE: this function was moved to network from the ergm package in network version 1.13

## See Also

See also [as.matrix.network.edgelist](#)

## Examples

```
data(emon)
as.edgelist(emon[[1]])
as.edgelist(emon[[1]],output="tibble")
# contrast with unsorted columns of
as.matrix.network.edgelist(emon[[1]])
```



matrix.type	one of "adjacency", "incidence", "edgelist", or NULL
attrname	optionally, the name of an edge attribute to use for edge values
...	additional arguments.
expand.bipartite	logical; if x is bipartite, should we return the full adjacency matrix (rather than the abbreviated, two-mode form)?
as.sna.edgelist	logical; should the edgelist be returned in sna edgelist form?
na.rm	logical; should missing edges/vertices be included in the edgelist formats? Ignored if as.sna.edgelist=TRUE.
attrnames	optionally, either a character vector of the names of edge attributes to use for edge values, or a numerical or logical vector to use as indices for selecting them from <code>list.edge.attributes(x)</code> or <code>list.vertex.attributes(x)</code> (depending on unit); passing TRUE therefore returns all edge attributes as columns
unit	whether a <code>tibble</code> of edge or vertex attributes should be returned.
store.eid	whether the edge ID should be stored in the third column ( <code>.eid</code> ).

### Details

If no matrix type is specified, `which.matrix.type` will be used to make an educated guess based on the shape of x. Where edge values are not specified, a dichotomous matrix will be assumed.

Edgelists returned by the `as.matrix` methods are by default in a slightly different form from the `sna` edgelist standard, but do contain the `sna` extended matrix attributes (see `as.network.matrix`). They should typically be compatible with `sna` library functions. To ensure compatibility, the `as.sna.edgelist` argument can be set (which returns an exact `sna` edgelist). The `as.edgelist` function also returns a similar edgelist matrix but with an enforced sorting.

For the `as.matrix` methods, if the `attrname` attribute is used to include a character attribute, the resulting edgelist matrix will be character rather than numeric. The `as_tibble` methods never coerce.

Note that adjacency matrices may also be obtained using the extraction operator. See the relevant man page for details. Also note that which attributes get returned by the `as_tibble` method by default depends on `unit`: by default no edge attributes are returned but all vertex attributes are.

### Value

For `as.matrix` methods, an adjacency, incidence, or edgelist matrix. For the `as_tibble` method, a `tibble` whose first two columns are `.head` and `.tail`, whose third column `.eid` is the edge ID, and whose subsequent columns are the requested edge attributes.

### Author(s)

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### References

Butts, C. T. (2008). "network: a Package for Managing Relational Data in R." *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

**See Also**

[which.matrix.type](#), [network](#), [network.extraction](#), [as.edgelist](#)

**Examples**

```
# Create a random network
m <- matrix(rbinom(25,4,0.159),5,5) # 50% density
diag(m) <- 0
g <- network(m, ignore.eval=FALSE, names.eval="a") # With values
g %e% "ac" <- letters[g %e% "a"]

# Coerce to matrix form
# No attributes:
as.matrix(g,matrix.type="adjacency")
as.matrix(g,matrix.type="incidence")
as.matrix(g,matrix.type="edgelist")
# Attributes:
as.matrix(g,matrix.type="adjacency",attrname="a")
as.matrix(g,matrix.type="incidence",attrname="a")
as.matrix(g,matrix.type="edgelist",attrname="a")
as.matrix(g,matrix.type="edgelist",attrname="ac")

# Coerce to a tibble:
library(tibble)
as_tibble(g)
as_tibble(g, attrnames=c("a","ac"))
as_tibble(g, attrnames=TRUE)
# Get vertex attributes instead:
as_tibble(g, unit = "vertices")

# Missing data handling:
g[1,2] <- NA
as.matrix(g,matrix.type="adjacency") # NA in the corresponding cell
as.matrix(g,matrix.type="edgelist", na.rm=TRUE) # (1,2) excluded
as.matrix(g,matrix.type="edgelist", na.rm=FALSE) # (1,2) included
as_tibble(g, attrnames="na", na.rm=FALSE) # Which edges are marked missing?

# Can also use the extraction operator
g[,] # Get entire adjacency matrix
g[1:2,3:5] # Obtain a submatrix
```

---

as.network.matrix

*Coercion from Matrices to Network Objects*


---

**Description**

as.network.matrix attempts to coerce its first argument to an object of class network.

**Usage**

```
## Default S3 method:
as.network(x, ...)

## S3 method for class 'matrix'
as.network(
  x,
  matrix.type = NULL,
  directed = TRUE,
  hyper = FALSE,
  loops = FALSE,
  multiple = FALSE,
  bipartite = FALSE,
  ignore.eval = TRUE,
  names.eval = NULL,
  na.rm = FALSE,
  edge.check = FALSE,
  ...
)
```

**Arguments**

x	a matrix containing an adjacency structure
...	additional arguments
matrix.type	one of "adjacency", "edgelist", "incidence", or NULL
directed	logical; should edges be interpreted as directed?
hyper	logical; are hyperedges allowed?
loops	logical; should loops be allowed?
multiple	logical; are multiplex edges allowed?
bipartite	count; should the network be interpreted as bipartite? If present (i.e., non-NULL) it is the count of the number of actors in the bipartite network. In this case, the number of nodes is equal to the number of actors plus the number of events (with all actors preceding all events). The edges are then interpreted as nondirected.
ignore.eval	logical; ignore edge values?
names.eval	optionally, the name of the attribute in which edge values should be stored
na.rm	logical; ignore missing entries when constructing the network?
edge.check	logical; perform consistency checks on new edges?

**Details**

Depending on `matrix.type`, one of three `edgeset` constructor methods will be employed to read the input matrix (see [edgeset.constructors](#)). If `matrix.type==NULL`, `which.matrix.type` will be used to guess the appropriate matrix type.

The coercion methods will recognize and attempt to utilize the `sna` extended matrix attributes where feasible. These are as follows:



- "n": taken to indicate number of vertices in the network.
- "bipartite": taken to indicate the network's bipartite attribute, where present.
- "vnames": taken to contain vertex names, where present.

These attributes are generally used with edgelists, and indeed data in sna edgelist format should be transparently converted in most cases. Where the extended matrix attributes are in conflict with the actual contents of `x`, results are not guaranteed (but the latter will usually override the former). For an edge list, the number of nodes in a network is determined by the number of unique nodes specified. If there are isolate nodes not in the edge list, the "n" attribute needs to be set. See example below.

### Value

An object of class network

### Author(s)

Carter T. Butts <[buttsc@uci.edu](mailto:buttsc@uci.edu)> and David Hunter <[dhunter@stat.psu.edu](mailto:dhunter@stat.psu.edu)>

### References

Butts, C. T. (2008). "network: a Package for Managing Relational Data in R." *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

### See Also

[edgeset.constructors](#), [network](#), [which.matrix.type](#)

### Examples

```
#Draw a random matrix
m<-matrix(rbinom(25,1,0.5),5)
diag(m)<-0

#Coerce to network form
g<-as.network.matrix(m,matrix.type="adjacency")

# edge list example. Only 4 nodes in the edge list.
m = matrix(c(1,2, 2,3, 3,4), byrow = TRUE, nrow=3)
attr(m, 'n') = 7
as.network(m, matrix.type='edgelist')
```

---

as.sociomatrix                      *Coerce One or More Networks to Sociomatrix Form*

---

### Description

as.sociomatrix takes adjacency matrices, adjacency arrays, [network](#) objects, or lists thereof, and returns one or more sociomatrices (adjacency matrices) as appropriate. This routine provides a useful input-agnostic front-end to functions which process adjacency matrices.

### Usage

```
as.sociomatrix(
  x,
  attrname = NULL,
  simplify = TRUE,
  expand.bipartite = FALSE,
  ...
)
```

### Arguments

x	an adjacency matrix, array, <a href="#">network</a> object, or list thereof.
attrname	optionally, the name of a network attribute to use for extracting edge values (if x is a <a href="#">network</a> object).
simplify	logical; should as.sociomatrix attempt to combine its inputs into an adjacency array (TRUE), or return them as separate list elements (FALSE)?
expand.bipartite	logical; if x is bipartite, should we return the full adjacency matrix (rather than the abbreviated, two-mode form)?
...	additional arguments for the coercion routine.

### Details

as.sociomatrix provides a more general means of coercing input into adjacency matrix form than [as.matrix.network](#). In particular, as.sociomatrix will attempt to coerce all input networks into the appropriate form, and return the resulting matrices in a regularized manner. If simplify==TRUE, as.sociomatrix attempts to return the matrices as a single adjacency array. If the input networks are of variable size, or if simplify==FALSE, the networks in question are returned as a list of matrices. In any event, a single input network is always returned as a lone matrix.

If attrname is given, the specified edge attribute is used to extract edge values from any [network](#) objects contained in x. Note that the same attribute will be used for all networks; if no attribute is specified, the standard dichotomous default will be used instead.

**Value**

One or more adjacency matrices. If all matrices are of the same dimension and `simplify==TRUE`, the matrices are joined into a single array; otherwise, the return value is a list of single adjacency matrices.

**Author(s)**

Carter T. Butts <butts@uci.edu>

**References**

Butts, C. T. (2008). "network: a Package for Managing Relational Data in R." *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

**See Also**

[as.matrix.network](#), [network](#)

**Examples**

```
#Generate an adjacency array
g<-array(rbinom(100,1,0.5),dim=c(4,5,5))

#Generate a network object
net<-network(matrix(rbinom(36,1,0.5),6,6))

#Coerce to adjacency matrix form using as.sociomatrix
as.sociomatrix(g,simplify=TRUE) #Returns as-is
as.sociomatrix(g,simplify=FALSE) #Returns as list
as.sociomatrix(net) #Coerces to matrix
as.sociomatrix(list(net,g)) #Returns as list of matrices
```

---

attribute.methods

*Attribute Interface Methods for the Network Class*

---

**Description**

These methods get, set, list, and delete attributes at the network, edge, and vertex level.

**Usage**

```
delete.edge.attribute(x, attrname, ...)

## S3 method for class 'network'
delete.edge.attribute(x, attrname, ...)
```

```
delete.network.attribute(x, attrname, ...)

## S3 method for class 'network'
delete.network.attribute(x, attrname, ...)

delete.vertex.attribute(x, attrname, ...)

## S3 method for class 'network'
delete.vertex.attribute(x, attrname, ...)

get.edge.attribute(x, ..., el)

## S3 method for class 'network'
get.edge.attribute(
  x,
  attrname,
  unlist = TRUE,
  na.omit = FALSE,
  null.na = FALSE,
  deleted.edges.omit = FALSE,
  ...,
  el
)

## S3 method for class 'list'
get.edge.attribute(
  x,
  attrname,
  unlist = TRUE,
  na.omit = FALSE,
  null.na = FALSE,
  deleted.edges.omit = FALSE,
  ...,
  el
)

get.edge.value(x, ...)

## S3 method for class 'network'
get.edge.value(
  x,
  attrname,
  unlist = TRUE,
  na.omit = FALSE,
  null.na = FALSE,
  deleted.edges.omit = FALSE,
  ...
)
```

```
## S3 method for class 'list'
get.edge.value(
  x,
  attrname,
  unlist = TRUE,
  na.omit = FALSE,
  null.na = FALSE,
  deleted.edges.omit = FALSE,
  ...
)

get.network.attribute(x, ...)

## S3 method for class 'network'
get.network.attribute(x, attrname, unlist = FALSE, ...)

get.vertex.attribute(x, ...)

## S3 method for class 'network'
get.vertex.attribute(
  x,
  attrname,
  na.omit = FALSE,
  null.na = TRUE,
  unlist = TRUE,
  ...
)

list.edge.attributes(x, ...)

## S3 method for class 'network'
list.edge.attributes(x, ...)

list.network.attributes(x, ...)

## S3 method for class 'network'
list.network.attributes(x, ...)

list.vertex.attributes(x, ...)

## S3 method for class 'network'
list.vertex.attributes(x, ...)

network.vertex.names(x)

network.vertex.names(x) <- value
```

```

set.edge.attribute(x, attrname, value, e, ...)

## S3 method for class 'network'
set.edge.attribute(x, attrname, value, e = seq_along(x$mel), ...)

set.edge.value(x, attrname, value, e, ...)

## S3 method for class 'network'
set.edge.value(x, attrname, value, e = seq_along(x$mel), ...)

set.network.attribute(x, attrname, value, ...)

## S3 method for class 'network'
set.network.attribute(x, attrname, value, ...)

set.vertex.attribute(x, attrname, value, v = seq_len(network.size(x)), ...)

## S3 method for class 'network'
set.vertex.attribute(x, attrname, value, v = seq_len(network.size(x)), ...)

```

### Arguments

<code>x</code>	an object of class <code>network</code> , or a list of edges (possibly <code>network\$mel</code> ) in <code>get.edge.attribute</code> .
<code>attrname</code>	the name of the attribute to get or set.
<code>...</code>	additional arguments
<code>e1</code>	Deprecated; use <code>x</code> instead.
<code>unlist</code>	logical; should retrieved attribute values be <a href="#">unlisted</a> prior to being returned?
<code>na.omit</code>	logical; should retrieved attribute values corresponding to vertices/edges marked as 'missing' be removed?
<code>null.na</code>	logical; should NULL values (corresponding to vertices or edges with no values set for the attribute) be replaced with NAs in output?
<code>deleted.edges.omit</code>	logical: should the elements corresponding to deleted edges be removed?
<code>value</code>	values of the attribute to be set; these should be in vector or list form for the edge and vertex cases, or matrix form for <code>set.edge.value</code> .
<code>e</code>	IDs for the edges whose attributes are to be altered.
<code>v</code>	IDs for the vertices whose attributes are to be altered.

### Details

The `list.attributes` functions return the names of all edge, network, or vertex attributes (respectively) in the network. All attributes need not be defined for all elements; the union of all extant attributes for the respective element type is returned.

The `get.attribute` functions look for an edge, network, or vertex attribute (respectively) with the name `attrname`, returning its values. Note that, to retrieve an edge attribute from all edges within a network `x`, `x$mel` should be used as the first argument to `get.edge.attribute`; `get.edge.value`

is a convenience function which does this automatically. As of v1.7.2, if a network object is passed to `get.edge.attribute` it will automatically call `get.edge.value` instead of returning `NULL`. When the parameters `na.omit`, or `deleted.edges.omit` are used, the position index of the attribute values returned will not correspond to the vertex/edge id. To preserved backward compatibility, if the edge attribute `attrname` does not exist for any edge, `get.edge.attribute` will still return `NULL` even if `null.na=TRUE`

`network.vertex.names` is a convenience function to extract the "vertex.names" attribute from all vertices.

The `set.attribute` functions allow one to set the values of edge, network, or vertex attributes. `set.edge.value` is a convenience function which allows edge attributes to be given in adjacency matrix form, and the assignment form of `network.vertex.names` is likewise a convenient front-end to `set.vertex.attribute` for vertex names. The `delete.attribute` functions, by contrast, remove the named attribute from the network, from all edges, or from all vertices (as appropriate). If `attrname` is a vector of attribute names, each will be removed in turn. These functions modify their arguments in place, although a pointer to the modified object is also (invisibly) returned.

Additional practical example of how to load and attach attributes are on the [loading.attributes](#) page.

Some attribute assignment/extraction can be performed conveniently through the various extraction/replacement operators, although they may be less efficient. See the associated man page for details.

### Value

For the `list.attributes` methods, a vector containing attribute names. For the `get.attribute` methods, a list containing the values of the attribute in question (or simply the value itself, for `get.network.attribute`). For the `set.attribute` and `delete.attribute` methods, a pointer to the updated network object.

### Note

As of version 1.9 the `set.vertex.attribute` function can accept and modify multiple attributes in a single call to improve efficiency. For this case `attrname` can be a list or vector of attribute names and `value` is a list of values corresponding to the elements of `attrname` (can also be a list of lists of values if elements in `v` should have different values).

### Author(s)

Carter T. Butts <[buttsc@uci.edu](mailto:buttsc@uci.edu)>

### References

Butts, C. T. (2008). "network: a Package for Managing Relational Data in R." *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

### See Also

[loading.attributes](#), [network](#), [as.network.matrix](#), [as.sociomatrix](#), [as.matrix.network](#), [network.extraction](#)

**Examples**

```

#Create a network with three edges
m<-matrix(0,3,3)
m[1,2]<-1; m[2,3]<-1; m[3,1]<-1
g<-network(m)

#Create a matrix of values corresponding to edges
mm<-m
mm[1,2]<-7; mm[2,3]<-4; mm[3,1]<-2

#Assign some attributes
set.edge.attribute(g,"myeval",3:5)
set.edge.value(g,"myeval2",mm)
set.network.attribute(g,"mygval","boo")
set.vertex.attribute(g,"myvval",letters[1:3])
network.vertex.names(g) <- LETTERS[1:10]

#List the attributes
list.edge.attributes(g)
list.network.attributes(g)
list.vertex.attributes(g)

#Retrieve the attributes
get.edge.attribute(g$mel,"myeval") #Note the first argument!
get.edge.value(g,"myeval")         #Another way to do this
get.edge.attribute(g$mel,"myeval2")
get.network.attribute(g,"mygval")
get.vertex.attribute(g,"myvval")
network.vertex.names(g)

#Purge the attributes
delete.edge.attribute(g,"myeval")
delete.edge.attribute(g,"myeval2")
delete.network.attribute(g,"mygval")
delete.vertex.attribute(g,"myvval")

#Verify that the attributes are gone
list.edge.attributes(g)
list.network.attributes(g)
list.vertex.attributes(g)

#Note that we can do similar things using operators
g %n% "mygval" <- "boo"           #Set attributes, as above
g %v% "myvval" <- letters[1:3]
g %e% "myeval" <- mm
g[, ,names.eval="myeval"] <- mm  #Another way to do this
g %n% "mygval"                   #Retrieve the attributes
g %v% "myvval"
g %e% "mevval"
as.sociomatrix(g,"myeval")       # Or like this

```



---

deletion.methods	<i>Remove Elements from a Network Object</i>
------------------	--

---

### Description

`delete.edges` removes one or more edges (specified by their internal ID numbers) from a network; `delete.vertices` performs the same task for vertices (removing all associated edges in the process).

### Usage

```
delete.edges(x, eid)
```

```
delete.vertices(x, vid)
```

### Arguments

<code>x</code>	an object of class network.
<code>eid</code>	a vector of edge IDs.
<code>vid</code>	a vector of vertex IDs.

### Details

Note that an edge's ID number corresponds to its order within `x$e1`. To determine edge IDs, see [get.edgeIDs](#). Likewise, vertex ID numbers reflect the order with which vertices are listed internally (e.g., the order of `x$o1` and `x$i1`, or that used by `as.matrix.network.adjacency`). When vertices are removed from a network, all edges having those vertices as endpoints are removed as well. When edges are removed, the remaining edge ids are NOT permuted and NULL elements will be left on the list of edges, which may complicate some functions that require eids (such as [set.edge.attribute](#)). The function [valid.eids](#) provides a means to determine the set of valid (non-NULL) edge ids.

Edges can also be added/removed via the extraction/replacement operators. See the associated man page for details.

### Value

Invisibly, a pointer to the updated network; these functions modify their arguments in place.

### Author(s)

Carter T. Butts <[butts@uci.edu](mailto:butts@uci.edu)>

### References

Butts, C. T. (2008). "network: a Package for Managing Relational Data in R." *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

**See Also**

[get.edgeIDs](#), [network.extraction](#), [valid.eids](#)

**Examples**

```
#Create a network with three edges
m<-matrix(0,3,3)
m[1,2]<-1; m[2,3]<-1; m[3,1]<-1
g<-network(m)

as.matrix.network(g)
delete.edges(g,2)           #Remove an edge
as.matrix.network(g)
delete.vertices(g,2)       #Remove a vertex
as.matrix.network(g)

#Can also remove edges using extraction/replacement operators
g<-network(m)
g[1,2]<-0                   #Remove an edge
g[,]
g[,]<-0                    #Remove all edges
g[,]
```

---

edgeset.constructors    *Edgeset Constructors for Network Objects*

---

**Description**

These functions convert relational data in matrix form to network edge sets.

**Usage**

```
network.bipartite(x, g, ignore.eval = TRUE, names.eval = NULL, ...)
network.adjacency(x, g, ignore.eval = TRUE, names.eval = NULL, ...)
network.edgelist(x, g, ignore.eval = TRUE, names.eval = NULL, ...)
network.incidence(x, g, ignore.eval = TRUE, names.eval = NULL, ...)
```

**Arguments**

x	a matrix containing edge information
g	an object of class network
ignore.eval	logical; ignore edge value information in x?
names.eval	a name for the edge attribute under which to store edge values, if any
...	possible additional arguments (such as <code>edge.check</code> )

## Details

Each of the above functions takes a network and a matrix as input, and modifies the supplied network object by adding the appropriate edges. `network.adjacency` takes `x` to be an adjacency matrix; `network.edgelist` takes `x` to be an edgelist matrix; and `network.incidence` takes `x` to be an incidence matrix. `network.bipartite` takes `x` to be a two-mode adjacency matrix where rows and columns reflect each respective mode (conventionally, actors and events); If `ignore.eval==FALSE`, (non-zero) edge values are stored as edgewise attributes with name `names.eval`. The `edge.check` argument can be added via `...` and will be passed to [add.edges](#).

Edgelist matrices to be used with `network.edgelist` should have one row per edge, with the first two columns indicating the sender and receiver of each edge (respectively). Edge values may be provided in additional columns. The edge attributes will be created with names corresponding to the column names unless alternate names are provided via `names.eval`. The vertices specified in the first two columns, which can be characters, are added to the network in default sort order. The edges are added in the order specified by the edgelist matrix.

Incidence matrices should contain one row per vertex, with one column per edge. A non-zero entry in the matrix means that the edge with the id corresponding to the column index will have an incident vertex with an id corresponding to the row index. In the directed case, negative cell values are taken to indicate tail vertices, while positive values indicate head vertices.

Results similar to `network.adjacency` can also be obtained by means of extraction/replacement operators. See the associated man page for details.

## Value

Invisibly, an object of class `network`; these functions modify their argument in place.

## Author(s)

Carter T. Butts <[butts@uci.edu](mailto:butts@uci.edu)> and David Hunter <[dhunter@stat.psu.edu](mailto:dhunter@stat.psu.edu)>

## References

Butts, C. T. (2008). “network: a Package for Managing Relational Data in R.” *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

## See Also

[loading.attributes](#), [network](#), [network.initialize](#), [add.edges](#), [network.extraction](#)

## Examples

```
#Create an arbitrary adjacency matrix
m<-matrix(rbinom(25,1,0.5),5,5)
diag(m)<-0

g<-network.initialize(5)    #Initialize the network
network.adjacency(m,g)     #Import the edge data

#Do the same thing, using replacement operators
g<-network.initialize(5)
```

```

g[,]<-m

# load edges from a data.frame via network.edgelist
edata <-data.frame(
  tails=c(1,2,3),
  heads=c(2,3,1),
  love=c('yes','no','maybe'),
  hate=c(3,-5,2),
  stringsAsFactors=FALSE
)

g<-network.edgelist(edata,network.initialize(4),ignore.eval=FALSE)
as.sociomatrix(g,attrname='hate')
g%e%'love'

# load edges from an incidence matrix
inci<-matrix(c(1,1,0,0, 0,1,1,0, 1,0,1,0),ncol=3,byrow=FALSE)
inci
g<-network.incidence(inci,network.initialize(4,directed=FALSE))
as.matrix(g)

```

---

emon

---

*Interorganizational Search and Rescue Networks (Drabek et al.)*


---

## Description

Drabek et al. (1981) provide seven case studies of emergent multi-organizational networks (EMONs) in the context of search and rescue (SAR) activities. Networks of interaction frequency are reported, along with several organizational attributes.

## Usage

```
data(emon)
```

## Format

A list of 7 `network` objects:

[[1]]	Cheyenne	network	Cheyenne SAR EMON
[[2]]	HurrFrederic	network	Hurricane Frederic SAR EMON
[[3]]	LakePomona	network	Lake Pomona SAR EMON
[[4]]	MtSi	network	Mt. Si SAR EMON
[[5]]	MtStHelens	network	Mt. St. Helens SAR EMON
[[6]]	Texas	network	Texas Hill Country SAR EMON
[[7]]	Wichita	network	Wichita Falls SAR EMON

Each network has one edge attribute:

Frequency    numeric    Interaction frequency (1-4; 1=most frequent)

Each network also has 8 vertex attributes:

Command.Rank.Score	numeric	Mean rank in the command structure
Decision.Rank.Score	numeric	Mean rank in the decision process
Formalization	numeric	Degree of formalization
Location	character	Location code
Paid.Staff	numeric	Number of paid staff
Sponsorship	character	Sponsorship type
vertex.names	character	Organization name
Volunteer.Staff	numeric	Number of volunteer staff

## Details

All networks collected by Drabek et al. reflect reported frequency of organizational interaction during the search and rescue effort; the (i,j) edge constitutes i's report regarding interaction with j, with non-adjacent vertices reporting no contact. Frequency is rated on a four-point scale, with 1 indicating the highest frequency of interaction. (Response options: 1="continuously", 2="about once an hour", 3="every few hours", 4="about once a day or less") This is stored within the "Frequency" edge attribute.

For each network, several covariates are recorded as vertex attributes:

**Command.Rank.Score** Mean (reversed) rank for the prominence of each organization in the command structure of the response, as judged by organizational informants.

**Decision.Rank.Score** Mean (reversed) rank for the prominence of each organization in decision making processes during the response, as judged by organizational informants.

**Formalization** An index of organizational formalization, ranging from 0 (least formalized) to 4 (most formalized).

**Localization** For each organization, "L" if the organization was sited locally to the impact area, "NL" if the organization was not sited near the impact area, "B" if the organization was sited at both local and non-local locations.

**Paid.Staff** Number of paid staff employed by each organization at the time of the response.

**Sponsorship** The level at which each organization was sponsored (e.g., "City", "County", "State", "Federal", and "Private").

**vertex.names** The identity of each organization.

**Volunteer.Staff** Number of volunteer staff employed by each organization at the time of the response.

Note that where intervals were given by the original source, midpoints have been substituted. For detailed information regarding data coding and procedures, see Drabek et al. (1981).

**Source**

Drabek, T.E.; Tamminga, H.L.; Kilijanek, T.S.; and Adams, C.R. (1981). *Data from Managing Multiorganizational Emergency Responses: Emergent Search and Rescue Networks in Natural Disaster and Remote Area Settings*. Program on Technology, Environment, and Man Monograph 33. Institute for Behavioral Science, University of Colorado.

**See Also**

[network](#)

**Examples**

```
data(emon) #Load the emon data set

#Plot the EMONS
par(mfrow=c(3,3))
for(i in 1:length(emon))
  plot(emon[[i]],main=names(emon)[i],edge.lwd="Frequency")
```

---

flo

*Florentine Wedding Data (Padgett)*

---

**Description**

This is a data set of Padgett (1994), consisting of weddings among leading Florentine families. This data is stored in symmetric adjacency matrix form.

**Usage**

```
data(flo)
```

**Source**

Padgett, John F. (1994). "Marriage and Elite Structure in Renaissance Florence, 1282-1500." Paper delivered to the Social Science History Association.

**References**

Wasserman, S. and Faust, K. (1994) *Social Network Analysis: Methods and Applications*, Cambridge: Cambridge University Press.

**See Also**

[network](#)

**Examples**

```

data(flo)
nflo<-network(flo,directed=FALSE) #Convert to network object form
all(nflo[,]==flo)                 #Trust, but verify
                                  #A fancy display:
plot(nflo,displaylabels=TRUE,boxed.labels=FALSE,label.cex=0.75)

```

---

get.edges

*Retrieve Edges or Edge IDs Associated with a Given Vertex*


---

**Description**

get.edges retrieves a list of edges incident on a given vertex; get.edgeIDs returns the internal identifiers for those edges, instead. Both allow edges to be selected based on vertex neighborhood and (optionally) an additional endpoint.

**Usage**

```

get.edgeIDs(
  x,
  v,
  alter = NULL,
  neighborhood = c("out", "in", "combined"),
  na.omit = TRUE
)

```

```

get.edges(
  x,
  v,
  alter = NULL,
  neighborhood = c("out", "in", "combined"),
  na.omit = TRUE
)

```

```

get.dyads.eids(x, tails, heads, neighborhood = c("out", "in", "combined"))

```

**Arguments**

x	an object of class network
v	a vertex ID
alter	optionally, the ID of another vertex
neighborhood	an indicator for whether we are interested in in-edges, out-edges, or both (relative to v). defaults to 'combined' for undirected networks
na.omit	logical; should we omit missing edges?

tails            a vector of vertex ID for the 'tails' (v) side of the dyad  
 heads           a vector of vertex ID for the 'heads' (alter) side of the dyad

### Details

By default, `get.edges` returns all out-, in-, or out- and in-edges containing `v`. `get.edgeIDs` is identical, save in its return value, as it returns only the ids of the edges. Specifying a vertex in `alter` causes these edges to be further selected such that `alter` must also belong to the edge – this can be used to extract edges between two particular vertices. Omission of missing edges is accomplished via `na.omit`. Note that for multiplex networks, multiple edges or edge ids can be returned.

The function `get.dyads.eids` simplifies the process of looking up the edge ids associated with a set of 'dyads' (tail and head vertex ids) for edges. It only is intended for working with non-multiplex networks and will return a warning and NA value for any dyads that correspond to multiple edges. The value `numeric(0)` will be returned for any dyads that do not have a corresponding edge.

### Value

For `get.edges`, a list of edges. For `get.edgeIDs`, a vector of edge ID numbers. For `get.dyads.eids`, a list of edge IDs corresponding to the dyads defined by the vertex ids in `tails` and `heads`

### Author(s)

Carter T. Butts <[butts@uci.edu](mailto:butts@uci.edu)>

### References

Butts, C. T. (2008). "network: a Package for Managing Relational Data in R." *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

### See Also

[get.neighborhood](#), [valid.eids](#)

### Examples

```
#Create a network with three edges
m<-matrix(0,3,3)
m[1,2]<-1; m[2,3]<-1; m[3,1]<-1
g<-network(m)

get.edges(g,1,neighborhood="out")
get.edgeIDs(g,1,neighborhood="in")
```



---

get.inducedSubgraph    *Retrieve Induced Subgraphs and Cuts*

---

### Description

Given a set of vertex IDs, `get.inducedSubgraph` returns the subgraph induced by the specified vertices (i.e., the vertices and all associated edges). Optionally, passing a second set of alters returns the cut from the first to the second set (i.e., all edges passing between the sets), along with the associated endpoints. Alternatively, passing in a vector of edge ids will induce a subgraph containing the specified edges and their incident vertices. In all cases, the result is returned as a network object, with all attributes of the selected edges and/or vertices (and any network attributes) preserved.

### Usage

```
get.inducedSubgraph(x, v, alters = NULL, eid = NULL)
```

x %s% v

### Arguments

x	an object of class network.
v	a vector of vertex IDs, or, for %s%, optionally a list containing two disjoint vectors of vertex IDs (see below).
alters	optionally, a second vector of vertex IDs. Must be disjoint with v.
eid	optionally, a numeric vector of valid edge ids in x that should be retained (cannot be used with v or alter)

### Details

For `get.inducedSubgraph`, v can be a vector of vertex IDs. If `alter=NULL`, the subgraph induced by these vertices is returned. Calling %s% with a single vector of vertices has an identical effect.

Where `alters` is specified, it must be a vector of IDs disjoint with v. Where both are given, the edges spanning v and `alters` are returned, along with the vertices in question. (Technically, only the edges really constitute the “cut,” but the vertices are included as well.) The same result can be obtained with the %s% operator by passing a two-element list on the right hand side; the first element is then interpreted as v, and the second as `alters`.

When `eid` is specified, the v and `alters` argument will be ignored and the subgraph induced by the specified edges and their incident vertices will be returned.

Any network, vertex, or edge attributes for the selected network elements are retained (although features such as vertex IDs and the network size will typically change). These are copies of the elements in the original network, which is not altered by this function.

### Value

A [network](#) object containing the induced subgraph.

**Author(s)**

Carter T. Butts <buttsc@uci.edu>

**See Also**

[network](#), [network.extraction](#)

**Examples**

```
#Load the Drabek et al. EMON data
data(emon)

#For the Mt. St. Helens, EMON, several types of organizations are present:
type<-emon$MtStHelens %v% "Sponsorship"

#Plot interactions among the state organizations
plot(emon$MtStHelens %s% which(type=="State"), displaylabels=TRUE)

#Plot state/federal interactions
plot(emon$MtStHelens %s% list(which(type=="State"),
  which(type=="Federal")), displaylabels=TRUE)

#Plot state interactions with everyone else
plot(emon$MtStHelens %s% list(which(type=="State"),
  which(type!="State")), displaylabels=TRUE)

# plot only interactions with frequency of 2
subG2<-get.inducedSubgraph(emon$MtStHelens,
  eid=which(emon$MtStHelens%e%'Frequency'==2))
plot(subG2,edge.label='Frequency')
```

---

get.neighborhood

*Obtain the Neighborhood of a Given Vertex*

---

**Description**

get.neighborhood returns the IDs of all vertices belonging to the in, out, or combined neighborhoods of v within network x.

**Usage**

```
get.neighborhood(x, v, type = c("out", "in", "combined"), na.omit = TRUE)
```

**Arguments**

x	an object of class network
v	a vertex ID
type	the neighborhood to be computed
na.omit	logical; should missing edges be ignored when obtaining vertex neighborhoods?

**Details**

Note that the combined neighborhood is the union of the in and out neighborhoods – as such, no vertex will appear twice.

**Value**

A vector containing the vertex IDs for the chosen neighborhood.

**Author(s)**

Carter T. Butts <butts@uci.edu>

**References**

Butts, C. T. (2008). “network: a Package for Managing Relational Data in R.” *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

Wasserman, S. and Faust, K. 1994. *Social Network Analysis: Methods and Applications*. Cambridge: Cambridge University Press.

**See Also**

[get.edges](#), [is.adjacent](#)

**Examples**

```
#Create a network with three edges
m<-matrix(0,3,3)
m[1,2]<-1; m[2,3]<-1; m[3,1]<-1
g<-network(m)

#Examine the neighborhood of vertex 1
get.neighborhood(g,1,"out")
get.neighborhood(g,1,"in")
get.neighborhood(g,1,"combined")
```

---

has.edges	<i>Determine if specified vertices of a network have any edges (are not isolates)</i>
-----------	---

---

**Description**

Returns a logical value for each specified vertex, indicating if it has any incident (in or out) edges. Checks all vertices by default

**Usage**

```
has.edges(net, v = seq_len(network.size(net)))
```

**Arguments**

net	a <a href="#">network</a> object to be queried
v	integer vector of vertex ids to check

**Value**

returns a logical vector with the same length as v, with TRUE if the vertex is involved in any edges, FALSE if it is an isolate.

**Author(s)**

skyebend

**Examples**

```
test<-network.initialize(5)
test[1,2]<-1
has.edges(test)
has.edges(test,v=5)
```

---

is.adjacent	<i>Determine Whether Two Vertices Are Adjacent</i>
-------------	--

---

**Description**

is.adjacent returns TRUE iff vi is adjacent to vj in x. Missing edges may be omitted or not, as per na.omit.

**Usage**

```
is.adjacent(x, vi, vj, na.omit = FALSE)
```

**Arguments**

x	an object of class network
vi	a vertex ID
vj	a second vertex ID
na.omit	logical; should missing edges be ignored when assessing adjacency?

**Details**

Vertex  $v$  is said to be adjacent to vertex  $v'$  within directed network  $G$  iff there exists some edge whose tail set contains  $v$  and whose head set contains  $v'$ . In the undirected case, head and tail sets are exchangeable, and thus  $v$  is adjacent to  $v'$  if there exists an edge such that  $v$  belongs to one endpoint set and  $v'$  belongs to the other. (In dyadic graphs, these sets are of cardinality 1, but this may not be the case where hyperedges are admitted.)

If an edge which would make  $v$  and  $v'$  adjacent is marked as missing (via its `na` attribute), then the behavior of `is.adjacent` depends upon `na.omit`. If `na.omit==FALSE` (the default), then the return value is considered to be NA unless there is also *another* edge from  $v$  to  $v'$  which is *not* missing (in which case the two are clearly adjacent). If `na.omit==TRUE`, on the other hand the missing edge is simply disregarded in assessing adjacency (i.e., it effectively treated as not present). It is important not to confuse “not present” with “missing” in this context: the former indicates that the edge in question does not belong to the network, while the latter indicates that the state of the corresponding edge is regarded as unknown. By default, all edge states are assumed “known” unless otherwise indicated (by setting the edge’s `na` attribute to TRUE; see [attribute.methods](#)).

Adjacency can also be determined via the extraction/replacement operators. See the associated man page for details.

**Value**

A logical, giving the status of the (i,j) edge

**Note**

Prior to version 1.4, `na.omit` was set to TRUE by default.

**Author(s)**

Carter T. Butts <[butts@uci.edu](mailto:butts@uci.edu)>

**References**

Butts, C. T. (2008). “network: a Package for Managing Relational Data in R.” *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

Wasserman, S. and Faust, K. 1994. *Social Network Analysis: Methods and Applications*. Cambridge: Cambridge University Press.

**See Also**

[get.neighborhood](#), [network.extraction](#), [attribute.methods](#)

## Examples

```
#Create a very simple graph
g<-network.initialize(3)
add.edge(g,1,2)
is.adjacent(g,1,2) #TRUE
is.adjacent(g,2,1) #FALSE
g[1,2]==1 #TRUE
g[2,1]==1 #FALSE
```

---

loading.attributes      *Examples of how to load vertex and edge attributes into networks*

---

## Description

Additional examples of how to manipulate network attributes using the functions documented in [attribute.methods](#)

## Details

The [attribute.methods](#) documentation gives details about the use of the specific network attribute methods such as `get.vertex.attribute` and `set.edge.attribute`. This document gives examples of how to load in and attach attribute data, drawing heavily on material from the Sunbelt statnet workshops <https://github.com/statnet/Workshops/wiki>.

The examples section below give a quick overview of:

- Loading in a matrix
- Attaching vertex attributes
- Attaching edge attributes from a matrix
- Loading in an edgelist
- Attaching edge attributes from an edgelist

The [read.table](#) documentation provides more information about reading data in from various tabular file formats prior to loading into a network. Note that the output is usually a `data.frame` object in which each columns is represented as a `factor`. This means that in some cases when the output is directly loaded into a network the variable values will appear as factor level numbers instead of text values. The `stringsAsFactors=FALSE` flag may help with this, but some columns may need to be converted using `as.numeric` or `as.character` where appropriate.

## References

- Acton, R. M., Jasny, L (2012) *An Introduction to Network Analysis with R and statnet* Sunbelt XXXII Workshop Series, March 13, 2012.
- Butts, C. T. (2008). “network: a Package for Managing Relational Data in R.” *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

**See Also**

[attribute.methods](#), [as.network.matrix](#), [as.sociomatrix](#), [as.matrix.network](#), [network.extraction](#)

**Examples**

```
# read in a relational data adjacency matrix

# LOADING IN A MATRIX
## Not run:
# can download matrix file from
# https://statnet.csde.washington.edu/trac/raw-attachment/wiki/Resources/relationalData.csv
# and download vertex attribute file from
# https://statnet.csde.washington.edu/trac/raw-attachment/wiki/Resources/vertexAttributes.csv

# load in relation matrix from file
relations <- read.csv("relationalData.csv",header=FALSE,stringsAsFactors=FALSE)

# convert to matrix format from data frame
relations <- as.matrix(relations)

# load in vertex attributes
nodeInfo <- read.csv("vertexAttributes.csv",header=TRUE,stringsAsFactors=FALSE)

## End(Not run)

print(relations) # peek at matrix
print(nodeInfo) # peek at attribute data

# Since our relational data has no row/column names, let's set them now
rownames(relations) <- nodeInfo$name
colnames(relations) <- nodeInfo$name

# create undirected network object from matrix
nrelations<-network(relations,directed=FALSE)

# it read in vertex names from matrix col names ...
network.vertex.names(nrelations)

# ATTACHING VERTEX ATTRIBUTES

# ... but could also set vertex.names with
nrelations%v%'vertex.names'<- nodeInfo$name

# load in other attributes
nrelations%v%"age" <- nodeInfo$age
nrelations%v%"sex" <- nodeInfo$sex
nrelations%v%"handed" <- nodeInfo$handed
nrelations%v%"lastDocVisit" <- nodeInfo$lastDocVisit
```

```

# Note: order of attributes in the data frame MUST match vertex ids
# otherwise the attribute will get assigned to the wrong vertex

# check that they got loaded
list.vertex.attributes(nrelations)

# what if we had an adjacency matrix like:
valuedMat<-matrix(c(1,2,3, 2,0,9.5,1,5,0),ncol=3,byrow=TRUE)
valuedMat

# make a network from it
valuedNet<-network(valuedMat,loops=TRUE,directed=TRUE)

# print it back out ...
as.matrix(valuedNet)

# wait, where did the values go!?!

# LOADING A MATRIX WITH VALUES

# to construct net from matrix with values:
valuedNet<-network(valuedMat,loops=TRUE,directed=TRUE,
  ignore.eval=FALSE,names.eval='myEdgeWeight')

# also have to specify the name of the attribute when converting to matrix
as.matrix(valuedNet,attrname='myEdgeWeight')

# ATTACHING EDGE ATTRIBUTES FROM A MATRIX

# maybe we have edge attributes of a different sort in another matrix like:
edgeAttrs<-matrix(c("B","Z","Q","W","A","E","L","P","A"),ncol=3,byrow=TRUE)
edgeAttrs

# we can still attach them
valuedNet<-set.edge.value(valuedNet,'someLetters',edgeAttrs)

# and extract them
as.matrix(valuedNet,attrname='someLetters')
valuedNet%e%'someLetters'

# but notice that some of the values didn't get used
# the ("A"s are missing) because there were no corresponding edges (loops)
# for the attribute to be attached to

# ATTACHING EDGE ATTRIBUTES FROM A LIST

# it is also possible to attach edge attributes directly from a list
edgeCols<-c("red","green","blue","orange","pink","brown","gray")
valuedNet<-set.edge.attribute(valuedNet,"edgeColors",edgeCols)

# but this can be risky, because we may not know the ordering of the edges,

```



```

# (especially if some have been deleted). Does "green" go with the edge from
# 1 to 2, or from 3 to 1?

# Usually if the edge data is only available in list form, it is safer to construct
# the network from an edgelist in the first place

# LOADING IN AN EDGELIST

# pretend we just loaded in this data.frame from a file
e1Data<-data.frame(
  from_id=c("1","2","3","1","3","1","2"),
  to_id=c("1", "1", "1", "2", "2", "3", "3"),
  myEdgeWeight=c(1, 2, 1, 2, 5, 3, 9.5),
  someLetters=c("B", "W", "L", "Z", "P", "Q", "E"),
  edgeCols=c("red","green","blue","orange","pink","brown","gray"),
  stringsAsFactors=FALSE
)

# peek at data
# each row corresponds to a relationship (edge) in the network
e1Data

# to make a network we just use the first two id columns
valuedNet2<-network(e1Data[,1:2],loops=TRUE)

# print it out
as.matrix(valuedNet2)

# has right edges, but no values

# to include values (with names from the columns)

valuedNet2<-network(e1Data,loops=TRUE)
list.edge.attributes(valuedNet2)
as.matrix(valuedNet2,attrname='someLetters')

```

---

missing.edges

*Identifying and Counting Missing Edges in a Network Object*


---

## Description

network.naedgcount returns the number of edges within a network object which are flagged as missing. The is.na.network method returns a new network containing the missing edges.

## Usage

```

## S3 method for class 'network'
is.na(x)

```

```
network.naedgecount(x, ...)
```

### Arguments

```
x          an object of class network
...        additional arguments, not used
```

### Details

The missingness of an edge is controlled by its `na` attribute (which is mandatory for all edges); `network.naedgecount` returns the number of edges for which `na==TRUE`. The `is.na` network method produces a new network object whose edges correspond to the missing (`na==TRUE`) edges of the original object, and is thus a convenient method of extracting detailed missingness information on the entire network. The network returned by `is.na` is guaranteed to have the same base network attributes (directedness, loopness, hypergraphicity, multiplexity, and bipartite constraint) as the original network object, but no other information is copied; note too that edge IDs are *not* preserved by this process (although adjacency obviously is). Since the resulting object is a `network`, standard coercion, `print/summary`, and other methods can be applied to it in the usual fashion.

It should be borne in mind that “missingness” in the sense used here reflects the assertion that an edge’s presence or absence is unknown, *not* that said edge is known not to be present. Thus, the `na` count for an empty graph is properly 0, since all edges are known to be absent. Edges can be flagged as missing by setting their `na` attribute to `TRUE` using `set.edge.attribute`, or by appropriate use of the network assignment operators; see below for an example of the latter.

### Value

`is.na(x)` returns a network object, and `network.naedgecount(x)` returns the number of missing edges.

### Author(s)

Carter T. Butts <[buttsc@uci.edu](mailto:buttsc@uci.edu)>

### References

Butts, C. T. (2008). “network: a Package for Managing Relational Data in R.” *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

### See Also

[network.edgecount](#), [get.network.attribute](#), [is.adjacent](#), [is.na](#)

### Examples

```
#Create an empty network with no missing data
g<-network.initialize(5)
g[,]          #No edges present...
network.naedgecount(g)==0 #Edges not present are not "missing"!
```

```

#Now, add some missing edges
g[1,,add.edges=TRUE]<-NA #Establish that 1's ties are unknown
g[,] #Observe the missing elements
is.na(g) #Observe in network form
network.naedgecount(g)==4 #These elements do count!
network.edgecount(is.na(g)) #Same as above

```

---

mixingmatrix

*Mixing matrix*


---

## Description

Return the mixing matrix for a network, on a given attribute.

## Usage

```

mixingmatrix(object, ...)

## S3 method for class 'network'
mixingmatrix(object, attrname, useNA = "ifany", expand.bipartite = FALSE, ...)

## S3 method for class 'mixingmatrix'
x[[...]]

## S3 method for class 'mixingmatrix'
x$name

## S3 method for class 'mixingmatrix'
is.directed(x, ...)

## S3 method for class 'mixingmatrix'
is.bipartite(x, ...)

## S3 method for class 'mixingmatrix'
print(x, ...)

```

## Arguments

object	a network or some other data structure for which a mixing matrix is meaningful.
...	arguments passed to <a href="#">table</a> .
attrname	a vertex attribute name.
useNA	one of "ifany", "no" or "always". Argument passed to <a href="#">table</a> . By default (useNA = "ifany") if there are any NAs on the attribute corresponding row <i>and</i> column will be contained in the result. See Details.

<code>expand.bipartite</code>	logical; if object is bipartite, should we return the <i>square</i> mixing matrix representing every level of <code>attrname</code> against every other level, or a <i>rectangular</i> matrix considering only levels present in each bipartition?
<code>x</code>	mixingmatrix object
<code>name</code>	name of the element to extract, one of "matrix" or "type"

### Details

Handling of missing values on the attribute `attrname` almost follows similar logic to `table`. If there are NAs on the attribute and `useNA="ifany"` (default) the result will contain both row and column for the missing values to ensure the resulting matrix is square (essentially calling `table` with `useNA="always"`). Also for that reason passing `exclude` parameter with `NULL`, `NA` or `NaN` is ignored with a warning as it may break the symmetry.

### Value

Function `mixingmatrix()` returns an object of class `mixingmatrix` extending `table` with a cross-tabulation of edges in the object according to the values of attribute `attrname` for the two incident vertices. If object is a *directed* network rows correspond to the "tie sender" and columns to the "tie receiver". If object is an *undirected* network there is no such distinction and the matrix is symmetrized. In both cases the matrix is square and all the observed values of the attribute `attrname` are represented in rows and columns. If object is a *bipartite* network and `expand.bipartite` is `FALSE` the resulting matrix does not have to be square as only the actually observed values of the attribute are shown for each partition, if `expand.bipartite` is `TRUE` the matrix will be square.

Functions `is.directed()` and `is.bipartite()` return `TRUE` or `FALSE`. The values will be identical for the input network object.

### Note

The `$` and `[[` methods are included only for backward-compatibility reason and will become defunct in future releases of the package.

### Examples

```
# Interaction ties between Lake Pomona SAR organizations by sponsorship type
# of tie sender and receiver (data from Drabek et al. 1981)
data(emon)
mixingmatrix(emon$LakePomona, "Sponsorship")
```

---

network

*Network Objects*

---

### Description

Construct, coerce to, test for and print network objects.

**Usage**

```
is.network(x)

as.network(x, ...)

network(
  x,
  vertex.attr = NULL,
  vertex.attrnames = NULL,
  directed = TRUE,
  hyper = FALSE,
  loops = FALSE,
  multiple = FALSE,
  bipartite = FALSE,
  ...
)

network.copy(x)

## S3 method for class 'data.frame'
as.network(
  x,
  directed = TRUE,
  vertices = NULL,
  hyper = FALSE,
  loops = FALSE,
  multiple = FALSE,
  bipartite = FALSE,
  bipartite_col = "is_actor",
  ...
)

## S3 method for class 'network'
print(
  x,
  matrix.type = which.matrix.type(x),
  mixingmatrices = FALSE,
  na.omit = TRUE,
  print.adj = FALSE,
  ...
)

## S3 method for class 'network'
summary(object, na.omit = TRUE, mixingmatrices = FALSE, print.adj = TRUE, ...)
```

**Arguments**

<code>x</code>	for network, a matrix giving the network structure in adjacency, incidence, or edgelist form; otherwise, an object of class network.
<code>...</code>	additional arguments.
<code>vertex.attr</code>	optionally, a list containing vertex attributes.
<code>vertex.attrnames</code>	optionally, a list containing vertex attribute names.
<code>directed</code>	logical; should edges be interpreted as directed?
<code>hyper</code>	logical; are hyperedges allowed?
<code>loops</code>	logical; should loops be allowed?
<code>multiple</code>	logical; are multiplex edges allowed?
<code>bipartite</code>	count; should the network be interpreted as bipartite? If present (i.e., non-NULL, non-FALSE) it is the count of the number of actors in the bipartite network. In this case, the number of nodes is equal to the number of actors plus the number of events (with all actors preceding all events). The edges are then interpreted as nondirected. Values of <code>bipartite==0</code> are permitted, indicating a bipartite network with zero-sized first partition.
<code>vertices</code>	If <code>x</code> is a <code>data.frame</code> , <code>vertices</code> is an optional <code>data.frame</code> containing the vertex attributes. The first column is assigned to the <code>"vertex.names"</code> and additional columns are used to set vertex attributes using their column names. If <code>bipartite</code> is TRUE, a logical column named <code>"is_actor"</code> (or the name of a column specified using the <code>bipartite_col</code> parameter) can be provided indicating which vertices should be considered as actors. If not provided, vertices referenced in the first column of <code>x</code> are assumed to be the network's actors. If your network has isolates (i.e. there are vertices referenced in <code>vertices</code> that are not referenced in <code>x</code> ), the <code>"is_actor"</code> column is required.
<code>bipartite_col</code>	character(1L), default: <code>"is_actor"</code> . The name of the logical column indicating which vertices should be considered as actors in bipartite networks.
<code>matrix.type</code>	one of <code>"adjacency"</code> , <code>"edgelist"</code> , <code>"incidence"</code> . See <a href="#">edgeset.constructors</a> for details and optional additional arguments
<code>mixingmatrices</code>	logical; print the mixing matrices for the discrete attributes?
<code>na.omit</code>	logical; omit summarization of missing attributes in network?
<code>print.adj</code>	logical; print the network adjacency structure?
<code>object</code>	an object of class network.

**Details**

`network` constructs a network class object from a matrix representation. If the `matrix.type` parameter is not specified, it will make a guess as to the intended `edgeset.constructors` function to call based on the format of these input matrices. If the class of `x` is not a matrix, network construction can be dispatched to other methods. For example, If the `ergm` package is loaded, `network()` can function as a shorthand for `as.network.numeric` with `x` as an integer specifying the number of nodes to be created in the random graph.

If the `ergm` package is loaded, `network` can function as a shorthand for `as.network.numeric` if `x` is an integer specifying the number of nodes. See the help page for `as.network.numeric` in `ergm` package for details.

`network.copy` creates a new `network` object which duplicates its supplied argument. (Direct assignment with `<-` should be used rather than `network.copy` in most cases.)

`as.network` tries to coerce its argument to a network, using the `as.network.matrix` functions if `x` is a matrix. (If the argument is already a network object, it is returned as-is and all other arguments are ignored.)

`is.network` tests whether its argument is a network (in the sense that it has class `network`).

`print.network` prints a network object in one of several possible formats. It also prints the list of global attributes of the network.

`summary.network` provides similar information.

### Value

`network`, `as.network`, and `print.network` all return a network class object; `is.network` returns `TRUE` or `FALSE`.

### Note

Between versions 0.5 and 1.2, direct assignment of a network object created a pointer to the original object, rather than a copy. As of version 1.2, direct assignment behaves in the same manner as `network.copy`. Direct use of the latter is thus superfluous in most situations, and is discouraged.

Many of the network package functions modify their network object arguments in-place. For example, `set.network.attribute(net, "myVal", 5)` will have the same effect as `net<-set.network.attribute(net, "myVal", 5)`. Unfortunately, the current implementation of in-place assignment breaks when the network argument is an element of a list or a named part of another object. So `set.network.attribute(myListOfNetworks[[1]], "myVal", 5)` will silently fail to modify its network argument, likely leading to incorrect output.

### Author(s)

Carter T. Butts <[buttsc@uci.edu](mailto:buttsc@uci.edu)> and David Hunter <[dhunter@stat.psu.edu](mailto:dhunter@stat.psu.edu)>

### References

Butts, C. T. (2008). "network: a Package for Managing Relational Data in R." *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

### See Also

[network.initialize](#), [attribute.methods](#), [as.network.matrix](#), [as.matrix.network](#), [deletion.methods](#), [edgeset.constructors](#), [network.indicators](#), [plot.network](#)

### Examples

```
m <- matrix(rbinom(25,1,.4),5,5)
diag(m) <- 0
```

```

g <- network(m, directed=FALSE)
summary(g)

h <- network.copy(g)      #Note: same as h<-g
summary(h)

# networks from data frames =====
#* simple networks =====
simple_edge_df <- data.frame(
  from = c("b", "c", "c", "d", "a"),
  to = c("a", "b", "a", "a", "b"),
  weight = c(1, 1, 2, 2, 3),
  stringsAsFactors = FALSE
)
simple_edge_df

as.network(simple_edge_df)

# simple networks with vertices =====
simple_vertex_df <- data.frame(
  name = letters[1:5],
  residence = c("urban", "rural", "suburban", "suburban", "rural"),
  stringsAsFactors = FALSE
)
simple_vertex_df

as.network(simple_edge_df, vertices = simple_vertex_df)

as.network(simple_edge_df,
  directed = FALSE, vertices = simple_vertex_df,
  multiple = TRUE
)

#* splitting multiplex data frames into multiple networks =====
simple_edge_df$relationship <- c(rep("friends", 3), rep("colleagues", 2))
simple_edge_df

lapply(split(simple_edge_df, f = simple_edge_df$relationship),
  as.network,
  vertices = simple_vertex_df
)

#* bipartite networks without isolates =====
bip_edge_df <- data.frame(
  actor = c("a", "a", "b", "b", "c", "d", "d", "e"),
  event = c("e1", "e2", "e1", "e3", "e3", "e2", "e3", "e1"),
  actor_enjoyed_event = rep(c(TRUE, FALSE), 4),
  stringsAsFactors = FALSE
)
bip_edge_df

bip_node_df <- data.frame(
  node_id = c("a", "e1", "b", "e2", "c", "e3", "d", "e"),

```



```

node_type = c(
  "person", "event", "person", "event", "person",
  "event", "person", "person"
),
color = c(
  "red", "blue", "red", "blue", "red", "blue",
  "red", "red"
),
stringsAsFactors = FALSE
)
bip_node_df

as.network(bip_edge_df, directed = FALSE, bipartite = TRUE)
as.network(bip_edge_df, directed = FALSE, vertices = bip_node_df, bipartite = TRUE)

#* bipartite networks with isolates =====
bip_nodes_with_isolates <- rbind(
  bip_node_df,
  data.frame(
    node_id = c("f", "e4"),
    node_type = c("person", "event"),
    color = c("red", "blue"),
    stringsAsFactors = FALSE
  )
)
# indicate which vertices are actors via a column named `is_actor`
bip_nodes_with_isolates$is_actor <- bip_nodes_with_isolates$node_type == "person"
bip_nodes_with_isolates

as.network(bip_edge_df,
  directed = FALSE, vertices = bip_nodes_with_isolates,
  bipartite = TRUE
)

#* hyper networks from data frames =====
hyper_edge_df <- data.frame(
  from = c("a/b", "b/c", "c/d/e", "d/e"),
  to = c("c/d", "a/b/e/d", "a/b", "d/e"),
  time = 1:4,
  stringsAsFactors = FALSE
)
tibble::as_tibble(hyper_edge_df)

# split "from" and "to" at `"/"`, coercing them to list columns
hyper_edge_df$from <- strsplit(hyper_edge_df$from, split = "/")
hyper_edge_df$to <- strsplit(hyper_edge_df$to, split = "/")
tibble::as_tibble(hyper_edge_df)

as.network(hyper_edge_df,
  directed = FALSE, vertices = simple_vertex_df,
  hyper = TRUE, loops = TRUE
)

```

```

# convert network objects back to data frames =====
simple_g <- as.network(simple_edge_df, vertices = simple_vertex_df)
as.data.frame(simple_g)
as.data.frame(simple_g, unit = "vertices")

bip_g <- as.network(bip_edge_df,
  directed = FALSE, vertices = bip_node_df,
  bipartite = TRUE
)
as.data.frame(bip_g)
as.data.frame(bip_g, unit = "vertices")

hyper_g <- as.network(hyper_edge_df,
  directed = FALSE, vertices = simple_vertex_df,
  hyper = TRUE, loops = TRUE
)
as.data.frame(hyper_g)
as.data.frame(hyper_g, unit = "vertices")

```

---

network.arrow

*Add Arrows or Segments to a Plot*


---

## Description

network.arrow draws a segment or arrow between two pairs of points; unlike [arrows](#) or [segments](#), the new plot element is drawn as a polygon.

## Usage

```

network.arrow(
  x0,
  y0,
  x1,
  y1,
  length = 0.1,
  angle = 20,
  width = 0.01,
  col = 1,
  border = 1,
  lty = 1,
  offset.head = 0,
  offset.tail = 0,
  arrowhead = TRUE,
  curve = 0,
  edge.steps = 50,
  ...
)

```

**Arguments**

<code>x0</code>	A vector of x coordinates for points of origin
<code>y0</code>	A vector of y coordinates for points of origin
<code>x1</code>	A vector of x coordinates for destination points
<code>y1</code>	A vector of y coordinates for destination points
<code>length</code>	Arrowhead length, in current plotting units
<code>angle</code>	Arrowhead angle (in degrees)
<code>width</code>	Width for arrow body, in current plotting units (can be a vector)
<code>col</code>	Arrow body color (can be a vector)
<code>border</code>	Arrow border color (can be a vector)
<code>lty</code>	Arrow border line type (can be a vector)
<code>offset.head</code>	Offset for destination point (can be a vector)
<code>offset.tail</code>	Offset for origin point (can be a vector)
<code>arrowhead</code>	Boolean; should arrowheads be used? (Can be a vector))
<code>curve</code>	Degree of edge curvature (if any), in current plotting units (can be a vector)
<code>edge.steps</code>	For curved edges, the number of steps to use in approximating the curve (can be a vector)
<code>...</code>	Additional arguments to <a href="#">polygon</a>

**Details**

`network.arrow` provides a useful extension of [segments](#) and [arrows](#) when fine control is needed over the resulting display. (The results also look better.) Note that edge curvature is quadratic, with `curve` providing the maximum horizontal deviation of the edge (left-handed). Head/tail offsets are used to adjust the end/start points of an edge, relative to the baseline coordinates; these are useful for functions like [plot.network](#), which need to draw edges incident to vertices of varying radii.

**Value**

None.

**Note**

`network.arrow` is a direct adaptation of [gplot.arrow](#) from the `sna` package.

**Author(s)**

Carter T. Butts <[buttsc@uci.edu](mailto:buttsc@uci.edu)>

**References**

Butts, C. T. (2008). “network: a Package for Managing Relational Data in R.” *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

**See Also**

[plot.network](#), [network.loop](#), [polygon](#)

**Examples**

```
#Plot two points
plot(1:2,1:2)

#Add an edge
network.arrow(1,1,2,2,width=0.01,col="red",border="black")
```

---

network.density	<i>Compute the Density of a Network</i>
-----------------	---

---

**Description**

network.density computes the density of its argument.

**Usage**

```
network.density(x, na.omit = TRUE, discount.bipartite = FALSE)
```

**Arguments**

x	an object of class network
na.omit	logical; omit missing edges from extant edges when assessing density?
discount.bipartite	logical; if x is bipartite, should “forbidden” edges be excluded from the count of potential edges?

**Details**

The density of a network is defined as the ratio of extant edges to potential edges. We do not currently consider edge values; missing edges are omitted from extent (but not potential) edge count when na.omit==TRUE.

**Value**

The network density.

**Warning**

network.density relies on network attributes (see [network.indicators](#)) to determine the properties of the underlying network object. If these are set incorrectly (e.g., multiple edges in a non-multiplex network, network coded with directed edges but set to “undirected”, etc.), surprising results may ensue.

**Author(s)**

Carter T. Butts <buttsc@uci.edu>

**References**

Butts, C. T. (2008). “network: a Package for Managing Relational Data in R.” *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

Wasserman, S. and Faust, K. (1994). *Social Network Analysis: Methods and Applications*. Cambridge: Cambridge University Press.

**See Also**

[network.edgcount](#), [network.size](#)

**Examples**

```
#Create an arbitrary adjacency matrix
m<-matrix(rbinom(25,1,0.5),5,5)
diag(m)<-0

g<-network.initialize(5)    #Initialize the network
network.density(g)         #Calculate the density
```

---

network.dyadcount	<i>Return the Number of (Possibly Directed) Dyads in a Network Object</i>
-------------------	---

---

**Description**

network.dyadcount returns the number of possible dyads within a network, removing those flagged as missing if desired. If the network is directed, directed dyads are counted accordingly.

**Usage**

```
## S3 method for class 'network'
network.dyadcount(x, na.omit = TRUE, ...)
```

**Arguments**

x	an object of class network
na.omit	logical; omit edges with na==TRUE from the count?
...	possible additional arguments, used by other implementations

**Details**

The return value `network.dyadcount` is equal to the number of dyads, minus the number of NULL edges (and missing edges, if `na.omit==TRUE`). If `x` is directed, the number of directed dyads is returned. If the network allows loops, the number of possible entries on the diagonal is added. Although the function does not give an error on multiplex networks or hypergraphs, the results probably don't make sense.

**Value**

The number of dyads in the network

**Author(s)**

Mark S. Handcock <handcock@stat.washington.edu>, skyebend

**References**

Butts, C. T. (2008). "network: a Package for Managing Relational Data in R." *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

**See Also**

[get.network.attribute](#), [network.edgcount](#), [is.directed](#)

**Examples**

```
#Create a directed network with three edges
m<-matrix(0,3,3)
m[1,2]<-1; m[2,3]<-1; m[3,1]<-1
g<-network(m)
network.dyadcount(g)==6           #Verify the directed dyad count
g<-network(m|t(m),directed=FALSE)
network.dyadcount(g)==3           #nC2 in undirected case
```

---

`network.edgcount`      *Return the Number of Edges in a Network Object*

---

**Description**

`network.edgcount` returns the number of edges within a network, removing those flagged as missing if desired.

**Usage**

```
## S3 method for class 'network'
network.edgcount(x, na.omit = TRUE, ...)
```

**Arguments**

x	an object of class network
na.omit	logical; omit edges with na==TRUE from the count?
...	additional arguments, used by extending functio

**Details**

The return value is the number of distinct edges within the network object, including multiplex edges as appropriate. (So if there are 3 edges from vertex i to vertex j, each contributes to the total edge count.)

The return value `network.edgcount` is in the present implementation related to the (required) `mnext` network attribute. `mnext` is an internal legacy attribute that currently indicates the index number of the next edge to be added to a network object. (Do not modify it unless you enjoy unfortunate surprises.) The number of edges returned by `network.edgcount` is equal to `x%n%"mnext"-1`, minus the number of NULL edges (and missing edges, if `na.omit==TRUE`). Note that `g%n%"mnext"-1` cannot, by itself, be counted upon to be an accurate count of the number of edges! As `mnext` is not part of the API (and is not guaranteed to remain), users and developers are urged to use `network.edgcount` instead.

**Value**

The number of edges

**Warning**

`network.edgcount` uses the real state of the network object to count edges, not the state it hypothetically should have. Thus, if you add extra edges to a non-multiplex network, directed edges to an undirected network, etc., the actual number of edges in the object will be returned (and not the number you would expect if you relied only on the putative number of possible edges as reflected by the [network.indicators](#)). Don't create network objects with contradictory attributes unless you know what you are doing.

**Author(s)**

Carter T. Butts <[buttsc@uci.edu](mailto:buttsc@uci.edu)>

**References**

Butts, C. T. (2008). "network: a Package for Managing Relational Data in R." *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

**See Also**

[get.network.attribute](#)

**Examples**

```
#Create a network with three edges
m<-matrix(0,3,3)
m[1,2]<-1; m[2,3]<-1; m[3,1]<-1
g<-network(m)
network.edgcount(g)==3 #Verify the edgcount
```

---

network.edgelabel      *Plots a label corresponding to an edge in a network plot.*

---

**Description**

Draws a text labels on (or adjacent to) the line segments connecting vertices on a network plot.

**Usage**

```
network.edgelabel(
  px0,
  py0,
  px1,
  py1,
  label,
  directed,
  loops = FALSE,
  cex,
  curve = 0,
  ...
)
```

**Arguments**

px0	vector of x coordinates of tail vertex of the edge
py0	vector of y coordinates of tail vertex of the edge
px1	vector of x coordinates of head vertex of the edge
py1	vector of y coordinate of head vertex of the edge
label	vector strings giving labels to be drawn for edge edge
directed	logical: is the underlying network directed? If FALSE, labels will be drawn in the middle of the line segment, otherwise in the first 3rd so that the labels for edges pointing in the opposite direction will not overlap.
loops	logical: if true, assuming the labels to be drawn belong to loop-type edges and render appropriately
cex	numeric vector giving the text expansion factor for each label
curve	numeric vector controlling the extent of edge curvature (0 = straight line edges)
...	additional arguments to be passed to <a href="#">text</a>



**Details**

Called internally by `plot.network` when `edge.label` parameter is used. For directed, non-curved edges, the labels are shifted towards the tail of the edge. Labels for curved edges are not shifted because opposite-direction edges curve the opposite way. Makes a crude attempt to shift labels to either side of line, and to draw the edge labels for self-loops near the vertex. No attempt is made to avoid overlap between vertex and edge labels.

**Value**

no value is returned but text will be rendered on the active plot

**Author(s)**

skyebend

---

network.extraction      *Extraction and Replacement Operators for Network Objects*

---

**Description**

Various operators which allow extraction or replacement of various components of a network object.

**Usage**

```
## S3 method for class 'network'
x[i, j, na.omit = FALSE]

## S3 replacement method for class 'network'
x[i, j, names.eval = NULL, add.edges = FALSE] <- value

x %e% attrname

x %e% attrname <- value

x %eattr% attrname

x %eattr% attrname <- value

x %n% attrname

x %n% attrname <- value

x %nattr% attrname

x %nattr% attrname <- value
```

```

x %v% attrname

x %v% attrname <- value

x %vattr% attrname

x %vattr% attrname <- value

```

### Arguments

<code>x</code>	an object of class <code>network</code> .
<code>i, j</code>	indices of the vertices with respect to which adjacency is to be tested. Empty values indicate that all vertices should be employed (see below).
<code>na.omit</code>	logical; should missing edges be omitted (treated as no-adjacency), or should NAs be returned? (Default: return NA on missing.)
<code>names.eval</code>	optionally, the name of an edge attribute to use for assigning edge values.
<code>add.edges</code>	logical; should new edges be added to <code>x</code> where edges are absent and the appropriate element of <code>value</code> is non-zero?
<code>value</code>	the value (or set thereof) to be assigned to the selected element of <code>x</code> .
<code>attrname</code>	the name of a network or vertex attribute (as appropriate).

### Details

Indexing for edge extraction operates in a manner analogous to `matrix` objects. Thus, `x[, ]` selects all vertex pairs, `x[1, -5]` selects the pairing of vertex 1 with all vertices except for 5, etc. Following this, it is acceptable for `i` and/or `j` to be logical vectors indicating which vertices are to be included. During assignment, an attempt is made to match the elements of `value` to the extracted pairs in an intelligent way; in particular, elements of `value` will be replicated if too few are supplied (allowing expressions like `x[1, ]<-1`). Where `names.eval==NULL`, zero and non-zero values are taken to indicate the presence of absence of edges. `x[2,4]<-6` thus adds a single (2,4) edge to `x`, and `x[2,4]<-0` removes such an edge (if present). If `x` is multiplex, assigning 0 to a vertex pair will eliminate *all* edges on that pair. Pairs are taken to be directed where `is.directed(x)==TRUE`, and undirected where `is.directed(x)==FALSE`.

If an edge attribute is specified using `names.eval`, then the provided values will be assigned to that attribute. When assigning values, only extant edges are employed (unless `add.edges==TRUE`); in the latter case, any non-zero assignment results in the addition of an edge where currently absent. If the attribute specified is not present on a given edge, it is added. Otherwise, any existing value is overwritten. The `%%` operator can also be used to extract/assign edge values; in those roles, it is respectively equivalent to `get.edge.value(x, attrname)` and `set.edge.value(x, attrname=attrname, value=value)` (if `value` is a matrix) and `set.edge.attribute(x, attrname=attrname, value=value)` (if `value` is anything else). That is, if `value` is a matrix, the assignment operator treats it as an adjacency matrix; and if not, it treats it as a vector (recycled as needed) in the internal ordering of edges (i.e., edge IDs), skipping over deleted edges. In no case will attributes be assigned to nonexisted edges.

The `%n%` and `%v%` operators serve as front-ends to the network and vertex extraction/assignment functions (respectively). In the extraction case, `x %n% attrname` is equivalent to `get.network.attribute(x, attrname)`, with `x %v% attrname` corresponding to `get.vertex.attribute(x, attrname)`. In assignment, the

respective equivalences are to `set.network.attribute(x, attrname, value)` and `set.vertex.attribute(x, attrname, value)`. Note that the `%%` assignment forms are generally slower than the named versions of the functions because they will trigger an additional internal copy of the network object.

The `%attr%`, `%nattr%`, and `%vattr%` operators are equivalent to `%e%`, `%n%`, and `%v%` (respectively). The short forms are more succinct, but may produce less readable code.

## Value

The extracted data, or none.

## Author(s)

Carter T. Butts <[buttsc@uci.edu](mailto:buttsc@uci.edu)>

## References

Butts, C. T. (2008). "network: a Package for Managing Relational Data in R." *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

## See Also

[is.adjacent](#), [as.sociomatrix](#), [attribute.methods](#), [add.edges](#), [network.operators](#), and [get.inducedSubgraph](#)

## Examples

```
#Create a random graph (inefficiently)
g<-network.initialize(10)
g[,]<-matrix(rbinom(100,1,0.1),10,10)
plot(g)

#Demonstrate edge addition/deletion
g[,]<-0
g[1,]<-1
g[2:3,6:7]<-1
g[,]

#Set edge values
g[, ,names.eval="boo"]<-5
as.sociomatrix(g,"boo")
#Assign edge values from a vector
g %e% "hoo" <- "wah"
g %e% "hoo"
g %e% "om" <- c("wow", "whee")
g %e% "om"
#Assign edge values as a sociomatrix
g %e% "age" <- matrix(1:100, 10, 10)
g %e% "age"
as.sociomatrix(g,"age")

#Set/retrieve network and vertex attributes
```

```

g %n% "blah" <- "Pork!"           #The other white meat?
g %n% "blah" == "Pork!"          #TRUE!
g %v% "foo" <- letters[10:1]      #Letter the vertices
g %v% "foo" == letters[10:1]     #All TRUE

```

---

network.indicators      *Indicator Functions for Network Properties*

---

## Description

Various indicators for properties of network class objects.

## Usage

```

has.loops(x)

is.bipartite(x, ...)

## S3 method for class 'network'
is.bipartite(x, ...)

is.directed(x, ...)

## S3 method for class 'network'
is.directed(x, ...)

is.hyper(x)

is.multiplex(x)

```

## Arguments

x	an object of class network
...	other arguments passed to/from other methods

## Details

These methods are the standard means of assessing the state of a network object; other methods can (and should) use these routines in governing their own behavior. As such, improper setting of the associated attributes may result in unpleasantly creative results. (See the `edge.check` argument to [add.edges](#) for an example of code which makes use of these network properties.)

The functions themselves behave as follows:

`has.loops` returns TRUE iff `x` is allowed to contain loops (or loop-like edges, in the hypergraphic case).

`is.bipartite` returns TRUE iff the `x` has been explicitly bipartite-coded. Values of `bipartite=NULL`, and `bipartite=FALSE` will evaluate to FALSE, numeric values of `bipartite>=0` will evaluate to

TRUE. (The value `bipartite==0` indicates that it is a bipartite network with a zero-sized first partition.) Note that `is.bipartite` refers only to the storage properties of `x` and how it should be treated by some algorithms; `is.bipartite(x)==FALSE` it does *not* mean that `x` cannot admit a bipartition!

`is.directed` returns TRUE iff the edges of `x` are to be interpreted as directed.

`is.hyper` returns TRUE iff `x` is allowed to contain hypergraphic edges.

`is.multiplex` returns TRUE iff `x` is allowed to contain multiplex edges.

### Value

TRUE or FALSE

### Author(s)

Carter T. Butts <[buttsc@uci.edu](mailto:buttsc@uci.edu)>

### References

Butts, C. T. (2008). “network: a Package for Managing Relational Data in R.” *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

### See Also

[network](#), [get.network.attribute](#), [set.network.attribute](#), [add.edges](#)

### Examples

```
g<-network.initialize(5)  #Initialize the network
is.bipartite(g)
is.directed(g)
is.hyper(g)
is.multiplex(g)
has.loops(g)
```

---

`network.initialize`      *Initialize a Network Class Object*

---

### Description

Create and initialize a network object with `n` vertices.

**Usage**

```
network.initialize(  
  n,  
  directed = TRUE,  
  hyper = FALSE,  
  loops = FALSE,  
  multiple = FALSE,  
  bipartite = FALSE  
)
```

**Arguments**

n	the number of vertices to initialize
directed	logical; should edges be interpreted as directed?
hyper	logical; are hyperedges allowed?
loops	logical; should loops be allowed?
multiple	logical; are multiplex edges allowed?
bipartite	count; should the network be interpreted as bipartite? If present (i.e., non-NULL) it is the count of the number of actors in the first mode of the bipartite network. In this case, the overall number of vertices is equal to the number of 'actors' (first mode) plus the number of 'events' (second mode), with the vertex.ids of all actors preceding all events. The edges are then interpreted as nondirected.

**Details**

Generally, `network.initialize` is called by other constructor functions as part of the process of creating a network.

**Value**

An object of class `network`

**Author(s)**

Carter T. Butts <[buttsc@uci.edu](mailto:buttsc@uci.edu)>

**References**

Butts, C. T. (2008). "network: a Package for Managing Relational Data in R." *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

**See Also**

[network](#), [as.network.matrix](#)

**Examples**

```
g<-network.initialize(5) #Create an empty graph on 5 vertices
```

---

network.layout	<i>Vertex Layout Functions for plot.network</i>
----------------	---

---

**Description**

Various functions which generate vertex layouts for the `plot.network` visualization routine.

**Usage**

```
network.layout.circle(nw, layout.par)
```

```
network.layout.fruchtermanreingold(nw, layout.par)
```

```
network.layout.kamadakawai(nw, layout.par)
```

**Arguments**

nw	a network object, as passed by <code>plot.network</code> .
layout.par	a list of parameters.

**Details**

Vertex layouts for network visualization pose a difficult problem – there is no single, “good” layout algorithm, and many different approaches may be valuable under different circumstances. With this in mind, `plot.network` allows for the use of arbitrary vertex layout algorithms via the `network.layout.*` family of routines. When called, `plot.network` searches for a `network.layout` function whose fourth name matches its mode argument (see `plot.network` help for more information); this function is then used to generate the layout for the resulting plot. In addition to the routines documented here, users may add their own layout functions as needed. The requirements for a `network.layout` function are as follows:

1. the first argument, `nw`, must be a network object;
2. the second argument, `layout.par`, must be a list of parameters (or NULL, if no parameters are specified); and
3. the return value must be a real matrix of dimension  $c(2, \text{network.size}(nw))$ , whose rows contain the vertex coordinates.

Other than this, anything goes. (In particular, note that `layout.par` could be used to pass additional matrices or other information, if needed. Alternately, it is possible to make layout methods that respond to covariates on the network object, which are maintained intact by `plot.network`.)

The `network.layout` functions currently supplied by default are as follows (with  $n = \text{network.size}(nw)$ ):

- circle** This function places vertices uniformly in a circle; it takes no arguments.
- fruchtermanreingold** This function generates a layout using a variant of Fruchterman and Reingold's force-directed placement algorithm. It takes the following arguments:
- layout.par\$niters** This argument controls the number of iterations to be employed. Larger values take longer, but will provide a more refined layout. (Defaults to 500.)
  - layout.par\$max.delta** Sets the maximum change in position for any given iteration. (Defaults to  $n$ .)
  - layout.par\$area** Sets the "area" parameter for the F-R algorithm. (Defaults to  $n^2$ .)
  - layout.par\$cool.exp** Sets the cooling exponent for the annealer. (Defaults to 3.)
  - layout.par\$repulse.rad** Determines the radius at which vertex-vertex repulsion cancels out attraction of adjacent vertices. (Defaults to  $\text{area} \cdot \log(n)$ .)
  - layout.par\$ncell** To speed calculations on large graphs, the plot region is divided at each iteration into  $ncell$  by  $ncell$  "cells", which are used to define neighborhoods for force calculation. Moderate numbers of cells result in fastest performance; too few cells (down to 1, which produces "pure" F-R results) can yield odd layouts, while too many will result in long layout times. (Defaults to  $n^{0.4}$ .)
  - layout.par\$cell.jitter** Jitter factor (in units of cell width) used in assigning vertices to cells. Small values may generate "grid-like" anomalies for graphs with many isolates. (Defaults to 0.5.)
  - layout.par\$cell.pointpointrad** Squared "radius" (in units of cells) such that exact point-interaction calculations are used for all vertices belonging to any two cells less than or equal to this distance apart. Higher values approximate the true F-R solution, but increase computational cost. (Defaults to 0.)
  - layout.par\$cell.pointcellrad** Squared "radius" (in units of cells) such that approximate point/cell interaction calculations are used for all vertices belonging to any two cells less than or equal to this distance apart (and not within the point/point radius). Higher values provide somewhat better approximations to the true F-R solution at slightly increased computational cost. (Defaults to 18.)
  - layout.par\$cell.cellcellrad** Squared "radius" (in units of cells) such that approximate cell/cell interaction calculations are used for all vertices belonging to any two cells less than or equal to this distance apart (and not within the point/point or point/cell radii). Higher values provide somewhat better approximations to the true F-R solution at slightly increased computational cost. Note that cells beyond this radius (if any) do not interact, save through edge attraction. (Defaults to  $ncell^2$ .)
  - layout.par\$seed.coord** A two-column matrix of initial vertex coordinates. (Defaults to a random circular layout.)
- kamadakawai** This function generates a vertex layout using a version of the Kamada-Kawai force-directed placement algorithm. It takes the following arguments:
- layout.par\$niters** This argument controls the number of iterations to be employed. (Defaults to 1000.)
  - layout.par\$sigma** Sets the base standard deviation of position change proposals. (Defaults to  $n/4$ .)
  - layout.par\$initemp** Sets the initial "temperature" for the annealing algorithm. (Defaults to 10.)
  - layout.par\$cool.exp** Sets the cooling exponent for the annealer. (Defaults to 0.99.)



- layout.par\$kkconst** Sets the Kamada-Kawai vertex attraction constant. (Defaults to  $n^2$ .)
- layout.par\$elen** Provides the matrix of interpoint distances to be approximated. (Defaults to the geodesic distances of `nw` after symmetrizing, capped at  $\sqrt{n}$ .)
- layout.par\$seed.coord** A two-column matrix of initial vertex coordinates. (Defaults to a gaussian layout.)

### Value

A matrix whose rows contain the x,y coordinates of the vertices of `d`.

### Note

The `network.layout` routines shown here are adapted directly from the `gplot.layout` routines of the `sna` package.

### Author(s)

Carter T. Butts <[butts@uci.edu](mailto:butts@uci.edu)>

### References

- Butts, C. T. (2008). "network: a Package for Managing Relational Data in R." *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>
- Fruchterman, T.M.J. and Reingold, E.M. (1991). "Graph Drawing by Force-directed Placement." *Software - Practice and Experience*, 21(11):1129-1164.
- Kamada, T. and Kawai, S. (1989). "An Algorithm for Drawing General Undirected Graphs." *Information Processing Letters*, 31(1):7-15.

### See Also

[plot.network](#)

---

network.loop

*Add Loops to a Plot*

---

### Description

`network.loop` draws a "loop" at a specified location; this is used to designate self-ties in `plot.network`.

### Usage

```
network.loop(
  x0,
  y0,
  length = 0.1,
  angle = 10,
  width = 0.01,
```

```

    col = 1,
    border = 1,
    lty = 1,
    offset = 0,
    edge.steps = 10,
    radius = 1,
    arrowhead = TRUE,
    xctr = 0,
    yctr = 0,
    ...
)

```

### Arguments

<code>x0</code>	a vector of x coordinates for points of origin.
<code>y0</code>	a vector of y coordinates for points of origin.
<code>length</code>	arrowhead length, in current plotting units.
<code>angle</code>	arrowhead angle (in degrees).
<code>width</code>	width for loop body, in current plotting units (can be a vector).
<code>col</code>	loop body color (can be a vector).
<code>border</code>	loop border color (can be a vector).
<code>lty</code>	loop border line type (can be a vector).
<code>offset</code>	offset for origin point (can be a vector).
<code>edge.steps</code>	number of steps to use in approximating curves.
<code>radius</code>	loop radius (can be a vector).
<code>arrowhead</code>	boolean; should arrowheads be used? (Can be a vector.)
<code>xctr</code>	x coordinate for the central location away from which loops should be oriented.
<code>yctr</code>	y coordinate for the central location away from which loops should be oriented.
<code>...</code>	additional arguments to <a href="#">polygon</a> .

### Details

`network.loop` is the companion to [network.arrow](#); like the latter, plot elements produced by `network.loop` are drawn using [polygon](#), and as such are scaled based on the current plotting device. By default, loops are drawn so as to encompass a circular region of radius `radius`, whose center is `offset` units from `x0,y0` and at maximum distance from `xctr,yctr`. This is useful for functions like [plot.network](#), which need to draw loops incident to vertices of varying radii.

### Value

None.

### Note

`network.loop` is a direct adaptation of [gplot.loop](#), from the `sna` package.

**Author(s)**

Carter T. Butts <butts@uci.edu>

**See Also**

[network.arrow](#), [plot.network](#), [polygon](#)

**Examples**

```
#Plot a few polygons with loops
plot(0,0,type="n",xlim=c(-2,2),ylim=c(-2,2),asp=1)
network.loop(c(0,0),c(1,-1),col=c(3,2),width=0.05,length=0.4,
  offset=sqrt(2)/4,angle=20,radius=0.5,edge.steps=50,arrowhead=TRUE)
polygon(c(0.25,-0.25,-0.25,0.25,NA,0.25,-0.25,-0.25,0.25),
  c(1.25,1.25,0.75,0.75,NA,-1.25,-1.25,-0.75,-0.75),col=c(2,3))
```

---

network.operators      *Network Operators*

---

**Description**

These operators allow for algebraic manipulation of relational structures.

**Usage**

```
## S3 method for class 'network'
e1 + e2

## S3 method for class 'network'
e1 - e2

## S3 method for class 'network'
e1 * e2

## S3 method for class 'network'
!e1

## S3 method for class 'network'
e1 | e2

## S3 method for class 'network'
e1 & e2

## S3 method for class 'network'
e1 %% e2
```

**Arguments**

e1	an object of class network.
e2	another network.

**Details**

In general, the binary network operators function by producing a new network object whose edge structure is based on that of the input networks. The properties of the new structure depend upon the inputs as follows:

- The size of the new network is equal to the size of the input networks (for all operators save %c%), which must themselves be of equal size. Likewise, the bipartite attributes of the inputs must match, and this is preserved in the output.
- If either input network allows loops, multiplex edges, or hyperedges, the output acquires this property. (If both input networks do not allow these features, then the features are disallowed in the output network.)
- If either input network is directed, the output is directed; if exactly one input network is directed, the undirected input is treated as if it were a directed network in which all edges are reciprocated.
- Supplemental attributes (including vertex names, but not edgewise missingness) are not transferred to the output.

The unary operator acts per the above, but with a single input. Thus, the output network has the same properties as the input, with the exception of supplemental attributes.

The behavior of the composition operator, %c%, is somewhat more complex than the others. In particular, it will return a bipartite network whenever either input network is bipartite *or* the vertex names of the two input networks do not match (or are missing). If both inputs are non-bipartite and have identical vertex names, the return value will have the same structure (but with loops). This behavior corresponds to the interpretation of the composition operator as counting walks on labeled sets of vertices.

Hypergraphs are not yet supported by these routines, but ultimately will be (as suggested by the above).

The specific operations carried out by these operators are generally self-explanatory in the non-multiplex case, but semantics in the latter circumstance bear elaboration. The following summarizes the behavior of each operator:

- + An  $(i, j)$  edge is created in the return graph for every  $(i, j)$  edge in each of the input graphs.
- An  $(i, j)$  edge is created in the return graph for every  $(i, j)$  edge in the first input that is not matched by an  $(i, j)$  edge in the second input; if the second input has more  $(i, j)$  edges than the first, no  $(i, j)$  edges are created in the return graph.
- \* An  $(i, j)$  edge is created for every pairing of  $(i, j)$  edges in the respective input graphs.
- %c% An  $(i, j)$  edge is created in the return graph for every edge pair  $(i, k), (k, j)$  with the first edge in the first input and the second edge in the second input.
- ! An  $(i, j)$  edge is created in the return graph for every  $(i, j)$  in the input not having an edge.
- | An  $(i, j)$  edge is created in the return graph if either input contains an  $(i, j)$  edge.

& An  $(i, j)$  edge is created in the return graph if both inputs contain an  $(i, j)$  edge.

Semantics for missing-edge cases follow from the above, under the interpretation that edges with `na==TRUE` are viewed as having an unknown state. Thus, for instance, `x*y` with `x` having 2  $(i, j)$  non-missing and 1 missing edge and `y` having 3 respective non-missing and 2 missing edges will yield an output network with 6 non-missing and 9 missing  $(i, j)$  edges.

### Value

The resulting network.

### Note

Currently, there is a naming conflict between the composition operator and the `%c%` operator in the [sna](#) package. This will be resolved in future releases; for the time being, one can determine which version of `%c%` is in use by varying which package is loaded first.

### Author(s)

Carter T. Butts <[buttsc@uci.edu](mailto:buttsc@uci.edu)>

### References

Butts, C. T. (2008). “network: a Package for Managing Relational Data in R.” *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

Wasserman, S. and Faust, K. (1994). *Social Network Analysis: Methods and Applications*. Cambridge: University of Cambridge Press.

### See Also

[network.extraction](#)

### Examples

```
#Create an in-star
m<-matrix(0,6,6)
m[2:6,1]<-1
g<-network(m)
plot(g)

#Compose g with its transpose
gcgt<-g %c% (network(t(m)))
plot(gcgt)
gcgt

#Show the complement of g
!g

#Perform various arithmetic and logical operations
(g+gcgt)[,] == (g|gcgt)[,]          #All TRUE
```

```
(g-gcgt)[,] == (g&!(gcgt))[,]  
(g*gcgt)[,] == (g&gcgt)[,]
```

---

network.size	<i>Return the Size of a Network</i>
--------------	-------------------------------------

---

### Description

network.size returns the order of its argument (i.e., number of vertices).

### Usage

```
network.size(x, ...)
```

### Arguments

x	an object of class network
...	additional arguments, not used

### Details

network.size(x) is equivalent to get.network.attribute(x, "n"); the function exists as a convenience.

### Value

The network size

### Author(s)

Carter T. Butts <butts@uci.edu>

### References

Butts, C. T. (2008). "network: a Package for Managing Relational Data in R." *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

### See Also

[get.network.attribute](#)

### Examples

```
#Initialize a network  
g<-network.initialize(7)  
network.size(g)
```

---

network.vertex      *Add Vertices to a Plot*

---

### Description

network.vertex adds one or more vertices (drawn using [polygon](#)) to a plot.

### Usage

```
network.vertex(  
  x,  
  y,  
  radius = 1,  
  sides = 4,  
  border = 1,  
  col = 2,  
  lty = NULL,  
  rot = 0,  
  lwd = 1,  
  ...  
)
```

### Arguments

x	a vector of x coordinates.
y	a vector of y coordinates.
radius	a vector of vertex radii.
sides	a vector containing the number of sides to draw for each vertex.
border	a vector of vertex border colors.
col	a vector of vertex interior colors.
lty	a vector of vertex border line types.
rot	a vector of vertex rotation angles (in degrees).
lwd	a vector of vertex border line widths.
...	Additional arguments to <a href="#">polygon</a>

### Details

network.vertex draws regular polygons of specified radius and number of sides, at the given coordinates. This is useful for routines such as [plot.network](#), which use such shapes to depict vertices.

### Value

None

**Note**

network.vertex is a direct adaptation of [gplot.vertex](#) from the sna package.

**Author(s)**

Carter T. Butts <[buttsc@uci.edu](mailto:buttsc@uci.edu)>

**References**

Butts, C. T. (2008). "network: a Package for Managing Relational Data in R." *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

**See Also**

[plot.network](#), [polygon](#)

**Examples**

```
#Open a plot window, and place some vertices
plot(0,0,type="n",xlim=c(-1.5,1.5),ylim=c(-1.5,1.5),asp=1)
network.vertex(cos((1:10)/10*2*pi),sin((1:10)/10*2*pi),col=1:10,
               sides=3:12,radius=0.1)
```

---

permute.vertexIDs	<i>Permute (Relabel) the Vertices Within a Network</i>
-------------------	--

---

**Description**

permute.vertexIDs permutes the vertices within a given network in the specified fashion. Since this occurs internally (at the level of vertex IDs), it is rarely of interest to end-users.

**Usage**

```
permute.vertexIDs(x, vids)
```

**Arguments**

x	an object of class <a href="#">network</a> .
vids	a vector of vertex IDs, in the order to which they are to be permuted.



## Details

permute.vertexIDs alters the internal ordering of vertices within a `network`. For most practical applications, this should not be necessary – de facto permutation can be accomplished by altering the appropriate vertex attributes. `permute.vertexIDs` is needed for certain other routines (such as `delete.vertices`), where it is used in various arcane and ineffable ways.

## Value

Invisibly, a pointer to the permuted network. `permute.vertexIDs` modifies its argument in place.

## Author(s)

Carter T. Butts <butts@uci.edu>

## References

Butts, C. T. (2008). “network: a Package for Managing Relational Data in R.” *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

## See Also

`network`

## Examples

```
data(flo)                #Load the Florentine Families data
nflo<-network(flo)      #Create a network object
n<-network.size(nflo)   #Get the number of vertices
permute.vertexIDs(nflo,n:1) #Reverse the vertices
all(flo[n:1,n:1]==as.sociomatrix(nflo)) #Should be TRUE
```

---

plot.network.default *Two-Dimensional Visualization for Network Objects*

---

## Description

`plot.network` produces a simple two-dimensional plot of network `x`, using optional attribute `at.tname` to set edge values. A variety of options are available to control vertex placement, display details, color, etc.

**Usage**

```
## S3 method for class 'network'
plot(x, ...)

## Default S3 method:
plot.network(x, attrname = NULL,
  label = network.vertex.names(x), coord = NULL, jitter = TRUE,
  thresh = 0, usearrows = TRUE, mode = "fruchtermanreingold",
  displayisolates = TRUE, interactive = FALSE, xlab = NULL,
  ylab = NULL, xlim = NULL, ylim = NULL, pad = 0.2, label.pad = 0.5,
  displaylabels = !missing(label), boxed.labels = FALSE, label.pos = 0,
  label.bg = "white", vertex.sides = 50, vertex.rot = 0, vertex.lwd=1,
  arrowhead.cex = 1, label.cex = 1, loop.cex = 1, vertex.cex = 1,
  edge.col = 1, label.col = 1, vertex.col = 2, label.border = 1,
  vertex.border = 1, edge.lty = 1, label.lty = NULL, vertex.lty = 1,
  edge.lwd = 0, edge.label = NULL, edge.label.cex = 1,
  edge.label.col = 1, label.lwd = par("lwd"), edge.len = 0.5,
  edge.curve = 0.1, edge.steps = 50, loop.steps = 20,
  object.scale = 0.01, uselen = FALSE, usecurve = FALSE,
  suppress.axes = TRUE, vertices.last = TRUE, new = TRUE,
  layout.par = NULL, ...)
```

**Arguments**

x	an object of class network.
...	additional arguments to <code>plot</code> .
attrname	an optional edge attribute, to be used to set edge values.
label	a vector of vertex labels, if desired; defaults to the vertex labels returned by <code>network.vertex.names</code> . If label has one element and it matches with a vertex attribute name, the value of the attribute will be used. Note that labels may be set but hidden by the <code>displaylabels</code> argument.
coord	user-specified vertex coordinates, in an <code>network.size(x)x2</code> matrix. Where this is specified, it will override the mode setting.
jitter	boolean; should the output be jittered?
thresh	real number indicating the lower threshold for tie values. Only ties of value $>$ thresh are displayed. By default, thresh=0.
usearrows	boolean; should arrows (rather than line segments) be used to indicate edges?
mode	the vertex placement algorithm; this must correspond to a <code>network.layout</code> function.
displayisolates	boolean; should isolates be displayed?
interactive	boolean; should interactive adjustment of vertex placement be attempted?
xlab	x axis label.
ylab	y axis label.
xlim	the x limits (min, max) of the plot.

ylim	the y limits of the plot.
pad	amount to pad the plotting range; useful if labels are being clipped.
label.pad	amount to pad label boxes (if boxed.labels==TRUE), in character size units.
displaylabels	boolean; should vertex labels be displayed?
boxed.labels	boolean; place vertex labels within boxes?
label.pos	position at which labels should be placed, relative to vertices. 0 results in labels which are placed away from the center of the plotting region; 1, 2, 3, and 4 result in labels being placed below, to the left of, above, and to the right of vertices (respectively); and label.pos>=5 results in labels which are plotted with no offset (i.e., at the vertex positions).
label.bg	background color for label boxes (if boxed.labels==TRUE); may be a vector, if boxes are to be of different colors.
vertex.sides	number of polygon sides for vertices; may be given as a vector or a vertex attribute name, if vertices are to be of different types. As of v1.12, radius of polygons are scaled so that all shapes have equal area
vertex.rot	angle of rotation for vertices (in degrees); may be given as a vector or a vertex attribute name, if vertices are to be rotated differently.
vertex.lwd	line width of vertex borders; may be given as a vector or a vertex attribute name, if vertex borders are to have different line widths.
arrowhead.cex	expansion factor for edge arrowheads.
label.cex	character expansion factor for label text.
loop.cex	expansion factor for loops; may be given as a vector or a vertex attribute name, if loops are to be of different sizes.
vertex.cex	expansion factor for vertices; may be given as a vector or a vertex attribute name, if vertices are to be of different sizes.
edge.col	color for edges; may be given as a vector, adjacency matrix, or edge attribute name, if edges are to be of different colors.
label.col	color for vertex labels; may be given as a vector or a vertex attribute name, if labels are to be of different colors.
vertex.col	color for vertices; may be given as a vector or a vertex attribute name, if vertices are to be of different colors.
label.border	label border colors (if boxed.labels==TRUE); may be given as a vector, if label boxes are to have different colors.
vertex.border	border color for vertices; may be given as a vector or a vertex attribute name, if vertex borders are to be of different colors.
edge.lty	line type for edge borders; may be given as a vector, adjacency matrix, or edge attribute name, if edge borders are to have different line types.
label.lty	line type for label boxes (if boxed.labels==TRUE); may be given as a vector, if label boxes are to have different line types.
vertex.lty	line type for vertex borders; may be given as a vector or a vertex attribute name, if vertex borders are to have different line types.

<code>edge.lwd</code>	line width scale for edges; if set greater than 0, edge widths are scaled by <code>edge.lwd*dat</code> . May be given as a vector, adjacency matrix, or edge attribute name, if edges are to have different line widths.
<code>edge.label</code>	if non-NULL, labels for edges will be drawn. May be given as a vector, adjacency matrix, or edge attribute name, if edges are to have different labels. A single value of TRUE will use edge ids as labels. NOTE: currently doesn't work for curved edges.
<code>edge.label.cex</code>	character expansion factor for edge label text; may be given as a vector or a edge attribute name, if edge labels are to have different sizes.
<code>edge.label.col</code>	color for edge labels; may be given as a vector or a edge attribute name, if labels are to be of different colors.
<code>label.lwd</code>	line width for label boxes (if <code>boxed.labels==TRUE</code> ); may be given as a vector, if label boxes are to have different line widths.
<code>edge.len</code>	if <code>uselength==TRUE</code> , curved edge lengths are scaled by <code>edge.len</code> .
<code>edge.curve</code>	if <code>usecurve==TRUE</code> , the extent of edge curvature is controlled by <code>edge.curve</code> . May be given as a fixed value, vector, adjacency matrix, or edge attribute name, if edges are to have different levels of curvature.
<code>edge.steps</code>	for curved edges (excluding loops), the number of line segments to use for the curve approximation.
<code>loop.steps</code>	for loops, the number of line segments to use for the curve approximation.
<code>object.scale</code>	base length for plotting objects, as a fraction of the linear scale of the plotting region. Defaults to 0.01.
<code>uselength</code>	boolean; should we use <code>edge.len</code> to rescale edge lengths?
<code>usecurve</code>	boolean; should we use <code>edge.curve</code> ?
<code>suppress.axes</code>	boolean; suppress plotting of axes?
<code>vertices.last</code>	boolean; plot vertices after plotting edges?
<code>new</code>	boolean; create a new plot? If <code>new==FALSE</code> , vertices and edges will be added to the existing plot.
<code>layout.par</code>	parameters to the <a href="#">network.layout</a> function specified in mode.

### Details

`plot.network` is the standard visualization tool for the `network` class. By means of clever selection of display parameters, a fair amount of display flexibility can be obtained. Vertex layout – if not specified directly using `coord` – is determined via one of the various available algorithms. These should be specified via the mode argument; see [network.layout](#) for a full list. User-supplied layout functions are also possible – see the aforementioned man page for details.

Note that where `is.hyper(x)==TRUE`, the network is converted to bipartite adjacency form prior to computing coordinates. If `interactive==TRUE`, then the user may modify the initial network layout by selecting an individual vertex and then clicking on the location to which this vertex is to be moved; this process may be repeated until the layout is satisfactory.

### Value

A two-column matrix containing the vertex positions as x,y coordinates

**Note**

plot.network is adapted (with minor modifications) from the `gplot` function of the `sna` library (authors: Carter T. Butts and Alex Montgomery); eventually, these two packages will be integrated.

**Author(s)**

Carter T. Butts <buttsc@uci.edu>

**References**

- Butts, C. T. (2008). "network: a Package for Managing Relational Data in R." *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>
- Wasserman, S., and Faust, K. (1994). *Social Network Analysis: Methods and Applications*. Cambridge: Cambridge University Press.

**See Also**

[network](#), [network.arrow](#), [network.loop](#), [network.vertex](#)

**Examples**

```
#Construct a sparse graph
m<-matrix(rbinom(100,1,1.5/9),10)
diag(m)<-0
g<-network(m)

#Plot the graph
plot(g)

#Load Padgett's marriage data
data(flo)
nflo<-network(flo)
#Display the network, indicating degree and flagging the Medicis
plot(nflo, vertex.cex=apply(flo,2,sum)+1, usearrows=FALSE,
      vertex.sides=3+apply(flo,2,sum),
      vertex.col=2+(network.vertex.names(nflo)=="Medici"))
```

---

plotArgs.network

*Expand and transform attributes of networks to values appropriate for arguments to plot.network*

---

**Description**

This is primarily an internal function called by `plot.network` or by external packages such as `ndtv` that want to prepare `plot.network` graphic arguments in a standardized way.

**Usage**

```
plotArgs.network(x, argName, argValue, d = NULL, edgetouse = NULL)
```

**Arguments**

x	a network object which is going to be plotted
argName	character, the name of <code>plot.network</code> graphic parameter
argValue	value for the graphic parameter named in <code>argName</code> which to be transformed/prepared. For many attributes, if this is a single character vector it will be assumed to be the name of a vertex or edge attribute to be extracted and transformed
d	is an edgelist matrix of edge values optionally used by some edge attribute functions
edgetouse	numeric vector giving set of edge ids to be used (in case some edges are not being shown) required by some attributes

**Details**

Given a network object, the name of graphic parameter argument to `plot.network` and value, it will if necessary transform the value, or extract it from the network, according to the description in [plot.network](#). For some attributes, if the value is the name of a vertex or edge attribute, the appropriate values will be extracted from the network before transformation.

**Value**

returns a vector with length corresponding to the number of vertices or edges (depending on the parameter type) giving the appropriately prepared values for the parameter type. If the values or specified attribute can not be processed correctly, and Error may occur.

**Author(s)**

skyebend@uw.edu

**See Also**

See also [plot.network](#)

**Examples**

```
net<-network.initialize(3)
set.vertex.attribute(net,'color',c('red','green','blue'))
set.vertex.attribute(net,'charm',1:3)
# replicate a single colorname value
plotArgs.network(net,'vertex.col','purple')
# map the 'color' attribute to color
plotArgs.network(net,'vertex.col','color')
# similarly for a numeric attribute ...
plotArgs.network(net,'vertex.cex',12)
plotArgs.network(net,'vertex.cex','charm')
```

---

prod.network                      *Combine Networks by Edge Value Multiplication*

---

### Description

Given a series of networks, `prod.network` attempts to form a new network by multiplication of edges. If a non-null `attrname` is given, the corresponding edge attribute is used to determine and store edge values.

### Usage

```
## S3 method for class 'network'  
prod(..., attrname = NULL, na.rm = FALSE)
```

### Arguments

<code>...</code>	one or more network objects.
<code>attrname</code>	the name of an edge attribute to use when assessing edge values, if desired.
<code>na.rm</code>	logical; should edges with missing data be ignored?

### Details

The network product method attempts to combine its arguments by edgewise multiplication (*not* composition) of their respective adjacency matrices; thus, this method is only applicable for networks whose adjacency coercion is well-behaved. Multiplication is effectively boolean unless `attrname` is specified, in which case this is used to assess edge values – net values of 0 will result in removal of the underlying edge.

Other network attributes in the return value are carried over from the first element in the list, so some persistence is possible (unlike the multiplication operator). Note that it is sometimes possible to “multiply” networks and raw adjacency matrices using this routine (if all dimensions are correct), but more exotic combinations may result in regrettably exciting behavior.

### Value

A [network](#) object.

### Author(s)

Carter T. Butts <[buttsc@uci.edu](mailto:buttsc@uci.edu)>

### References

Butts, C. T. (2008). “network: a Package for Managing Relational Data in R.” *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

### See Also

[network.operators](#)

## Examples

```
#Create some networks
g<-network.initialize(5)
h<-network.initialize(5)
i<-network.initialize(5)
g[1:3,,names.eval="marsupial",add.edges=TRUE]<-1
h[1:2,,names.eval="marsupial",add.edges=TRUE]<-2
i[1,,names.eval="marsupial",add.edges=TRUE]<-3

#Combine by addition
pouch<-prod(g,h,i,attrname="marsupial")
pouch[,,] #Edge values in the pouch?
as.sociomatrix(pouch,attrname="marsupial") #Recover the marsupial
```

---

read.paj	<i>Read a Pajek Project or Network File and Convert to an R 'Network' Object</i>
----------	--

---

## Description

Return a (list of) [network](#) object(s) after reading a corresponding .net or .paj file. The code accepts ragged array edgelist, but cannot currently handle 2-mode, multirelational (e.g. KEDS), or networks with entries for both edges and arcs (e.g. GD-a99m). See [network](#), [statnet](#), or [sna](#) for more information.

## Usage

```
read.paj(
  file,
  verbose = FALSE,
  debug = FALSE,
  edge.name = NULL,
  simplify = FALSE,
  time.format = c("pajekTiming", "networkDynamic")
)
```

## Arguments

file	the name of the file whence the data are to be read. If it does not contain an absolute path, the file name is relative to the current working directory (as returned by <a href="#">getwd</a> ). file can also be a complete URL.
verbose	logical: Should longer descriptions of the reading and coercion process be printed out?
debug	logical: Should very detailed descriptions of the reading and coercion process be printed out? This is typically used to debug the reading of files that are corrupted on coercion.



edge.name	optional name for the edge variable read from the file. The default is to use the value in the project file if found.
simplify	Should the returned network be simplified as much as possible and saved? The values specifies the name of the file which the data are to be stored. If it does not contain an absolute path, the file name is relative to the current working directory (see <a href="#">getwd</a> ). If specify is TRUE the file name is the name file.
time.format	if the network has timing information attached to edges/vertices, how should it be processed? 'pajekTiming' will attach the timing information unchanged in an attribute named pajek.timing. 'networkDynamic' will translate it to a spell matrix format, attach it as an 'activity' attribute and add the class 'networkDynamic' – formatting it for use by the networkDynamic package.

## Details

If the `*Vertices` block includes the optional graphic attributes (coordinates, shape, size, etc.) they will be read attached to the network as vertex attributes but values will not be interpreted (i.e. Pajek's color names will not be translated to R color names). Vertex attributes included in a `*Vector` block will be attached as vertex attributes.

Edges or Arc weights in the `*Arcs` or `*Edges` block are include in the network as an attribute with the same name as the network. If no weight is included, a default weight of 1 is used. Optional graphic attributes or labels will be attached as edge attributes.

If the file contains an empty `Arcs` block, an undirected network will be returned. Otherwise the network will be directed, with two edges (one in each direction) added for every row in the `*Edges` block.

If the `*Vertices`, `*Arcs` or `*Edges` blocks having timing information included in the rows (indicated by `. . .` tokens), it will be attached to the vertices with behavior determined by the `time.format` option. If the 'networkDynamic' format is used, times will be translated to networkDynamic's spell model with the assumption that the original Pajek representation was indicating discrete time chunks. For example "[5-10]" will become the spell [5,11], "[2-\*]" will become [2,Inf] and "[7]" will become [7,8]. See documentation for networkDynamic's `?activity.attribute` for details.

The `*Arcslist`, `*Edgelist` and `*Events` blocks are not yet supported.

As there is no known single complete specification for the file format, parsing behavior has been inferred from references and examples below.

## Value

The structure of the object returned by `read.paj` depends on the contents of the file it parses.

- if input file contains information about a single 'network' object (i.e .net input file) a single network object is returned with attribute data set appropriately if possible. or a list of networks (for .paj input).
- if input file contains multiple sets of relations for a single network, a list of network objects ('network.series') is returned, along with a formula object?.
- if input .paj file contains additional information (like partition information), or multiple `*Network` definitions a two element list is returned. The first element is a list of all the network objects created, and the second is a list of partitions, etc. (how are these matched up)

**Author(s)**

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**References**

Batagelj, Vladimir and Mrvar, Andrej (2011) Pajek Reference Manual version 2.05 <http://vlado.fmf.uni-lj.si/pub/networks/pajek/doc/pajekman.pdf> Section 5.3 pp 73-79  
 Batageli, Vladimir (2008) "Network Analysis Description of Networks" <http://vlado.fmf.uni-lj.si/pub/networks/doc/ECPR/08/ECPR01.pdf>  
 Pajek Datasets <http://vlado.fmf.uni-lj.si/pub/networks/data/esna/>

**See Also**

[network](#)

**Examples**

```
## Not run:
require(network)

par(mfrow=c(2,2))

test.net.1 <- read.paj("http://vlado.fmf.uni-lj.si/pub/networks/data/GD/gd98/A98.net")
plot(test.net.1,main=test.net.1%n%'title')

test.net.2 <- read.paj("http://vlado.fmf.uni-lj.si/pub/networks/data/mix/USAir97.net")
# plot using coordinates from the file in the file
plot(test.net.2,main=test.net.2%n%'title',
      coord=cbind(test.net.2%v%'x',
                  test.net.2%v%'y'),
      jitter=FALSE)

# read .paj project file
# notice output has $networks and $partitions
read.paj('http://vlado.fmf.uni-lj.si/vlado/podstat/A0/net/Tina.paj')

## End(Not run)
```

---

sum.network

*Combine Networks by Edge Value Addition*

---

**Description**

Given a series of networks, sum.network attempts to form a new network by accumulation of edges. If a non-null attrname is given, the corresponding edge attribute is used to determine and store edge values.

**Usage**

```
## S3 method for class 'network'
sum(..., attrname = NULL, na.rm = FALSE)
```

**Arguments**

```
...           one or more network objects.
attrname      the name of an edge attribute to use when assessing edge values, if desired.
na.rm        logical; should edges with missing data be ignored?
```

**Details**

The network summation method attempts to combine its arguments by addition of their respective adjacency matrices; thus, this method is only applicable for networks whose adjacency coercion is well-behaved. Addition is effectively boolean unless `attrname` is specified, in which case this is used to assess edge values – net values of 0 will result in removal of the underlying edge.

Other network attributes in the return value are carried over from the first element in the list, so some persistence is possible (unlike the addition operator). Note that it is sometimes possible to “add” networks and raw adjacency matrices using this routine (if all dimensions are correct), but more exotic combinations may result in regrettably exciting behavior.

**Value**

A [network](#) object.

**Author(s)**

Carter T. Butts <[buttsc@uci.edu](mailto:buttsc@uci.edu)>

**References**

Butts, C. T. (2008). “network: a Package for Managing Relational Data in R.” *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

**See Also**

[network.operators](#)

**Examples**

```
#Create some networks
g<-network.initialize(5)
h<-network.initialize(5)
i<-network.initialize(5)
g[1,,names.eval="marsupial",add.edges=TRUE]<-1
h[1:2,,names.eval="marsupial",add.edges=TRUE]<-2
i[1:3,,names.eval="marsupial",add.edges=TRUE]<-3
```

```
#Combine by addition
pouch<-sum(g,h,i,attrname="marsupial")
pouch[,] #Edge values in the pouch?
as.sociomatrix(pouch,attrname="marsupial") #Recover the marsupial
```

---

valid.eids

*Get the ids of all the edges that are valid in a network*

---

### Description

Returns a vector of valid edge ids (corresponding to non-NULL edges) for a network that may have some deleted edges.

### Usage

```
valid.eids(x)
```

### Arguments

x a network object, possibly with some deleted edges.

### Details

The edge ids used in the network package are positional indices on the internal "mel" list. When edges are removed using [delete.edges](#) NULL elements are left on the list. The function `valid.eids` returns the ids of all the valid (non-null) edge ids for its network argument.

### Value

a vector of integer ids corresponding to the non-null edges in x

### Note

If it is known that x has no deleted edges, `seq_along(x$mel)` is a faster way to generate the sequence of possible edge ids.

### Author(s)

skyebend

### See Also

See also [delete.edges](#)

## Examples

```
net<-network.initialize(100)
add.edges(net,1:99,2:100)
delete.edges(net,eid=5:95)
# get the ids of the non-deleted edges
valid.eids(net)
```

---

which.matrix.type      *Heuristic Determination of Matrix Types for Network Storage*

---

## Description

which.matrix.type attempts to choose an appropriate matrix expression for a network object, or (if its argument is a matrix) attempts to determine whether the matrix is of type adjacency, incidence, or edgelist.

## Usage

```
which.matrix.type(x)
```

## Arguments

x                      a matrix, or an object of class network

## Details

The heuristics used to determine matrix types are fairly arbitrary, and should be avoided where possible. This function is intended to provide a modestly intelligent fallback option when explicit identification by the user is not possible.

## Value

One of "adjacency", "incidence", or "edgelist"

## Author(s)

David Hunter <dhunter@stat.psu.edu>

## References

Butts, C. T. (2008). "network: a Package for Managing Relational Data in R." *Journal of Statistical Software*, 24(2). <https://www.jstatsoft.org/v24/i02/>

## See Also

[as.matrix.network](#), [as.network.matrix](#)

**Examples**

```
#Create an arbitrary adjacency matrix
m<-matrix(rbinom(25,1,0.5),5,5)
diag(m)<-0

#Can we guess the type?
which.matrix.type(m)

#Try the same thing with a network
g<-network(m)
which.matrix.type(g)
which.matrix.type(as.matrix.network(g,matrix.type="incidence"))
which.matrix.type(as.matrix.network(g,matrix.type="edgelist"))
```

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