The Nimrod Routing Architecture

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Nimrod Goals

- Support an internetwork of arbitrary size.
- Provide service-specific routing.
- Admit incremental deployment.

Environmental Constraints of the Internet

- Projected growth to billions of networks.
- Diverse communications media including terrestrial and satellite, wireline and wireless, multiaccess and point-to-point.
- Users desire low-cost service that meets applications' traffic handling requirements in terms of delay, throughput, reliability, and security.
- Service provider expected revenues dictate the services they offer, to whom, for what purposes, when, and for what fees.
- Mobility of processes, hosts, and networks.

Nimrod Features

- Representation of internetwork connectivity and services at multiple levels of abstraction.
- Localized route generation based on “maps” and service requirements.
- Source-directed and destination-directed packet forwarding along “flows.”
- Separate spaces to identify “what,” “where,” and “how to get there.”

Scalability

- Clustering of internetwork physical assets and abstraction of routing information relating to them.

- Restricting automatic distribution of routing information and obtaining detailed information through explicit queries.

- Selecting feasible but not necessarily optimal routes and localizing route generation at session sources and destinations.

Endpoints, EIDs

- An endpoint represents a user of the network layer—e.g., a transport layer entity.
- Each endpoint has at least one endpoint identifier (EID).
- EIDs are globally unique, computer friendly, relatively short bit strings which have no topological significance whatsoever. (For ease of management, EIDs might be organized hierarchically, but this is not necessary.)
- Users need not ever see an EID.

Maps

- Network information used for routing is organized as Maps.
- A map expresses the available connectivity between different points of a network.
- Different maps can represent the same region of a physical network at different levels of detail.
- A map is a graph composed of nodes and arcs.

Connectivity Specifications

By connectivity between two points we mean the available services and the restrictions on their use. The following are examples of connectivity specifications:

- "Between these two points, there exists best-effort service with no restrictions."
- "Between these two points, guaranteed 10 ms. delay can be arranged for traffic streams whose rate is below 1 Mbyte/sec and that have low (specified) burstiness."
- "Between these two points, best-effort service is offered as long as the traffic originates and is destined to research organizations."

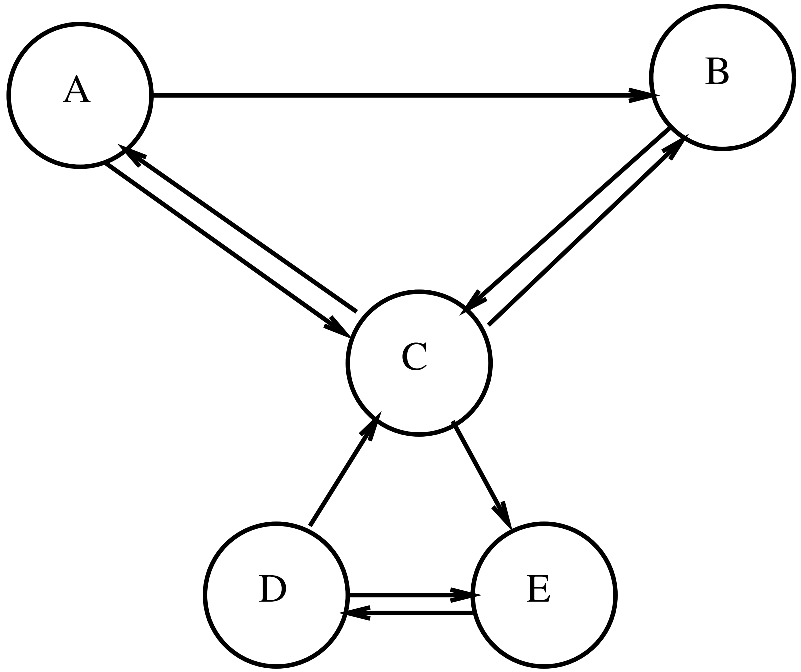
Nodes

- A node represents a connected region of the physical network.
- The region of the network represented by a node can be as large or as small as desired.
- Properties of nodes are contained in attributes associated with them.

Arcs

- Arcs are unidirectional.
- Arcs have no attributes.
- An arc has two distinguishable ends: a head and a tail. (Arcs are often visualized and drawn as arrows; the head of the arc corresponds to the head of the arrow.) The head and tail of an arc are each connected to a node.
- Between two given nodes, there can be only one arc in each direction. Arcs always connect different nodes.

Example Map



Locators

- The distinguishable components of a map are called basic topological entities (BTEs): nodes, arcs, and connectivity specifications.
- A locator is a string of binary digits that identifies a BTE in a map. Different BTEs have necessarily different locators. A given BTE is assigned only one locator.
- Locators specify *where* a BTE is in the network.
- If where you are in the network changes, your locator changes. You cannot take your locator with you.
- A locator does *not* specify a route to the BTE.

- A given physical element of the network might implement more than one BTE—for example, a router that is part of two different nodes.

Locators II

- All routing map information is expressed in terms of locators; routing selections are based on locators. EIDs are not used in making Nimrod routing decisions.

- The locator of an arc is prefixed by the locator of the node attached to the tail of the arc (the node the arc “leaves”).

- Nimrod requires locators sharing a prefix to be assigned to a contiguous region of the network.

- Two elements of the network that have been assigned locators that share a prefix should be connected to each other with elements that themselves have been assigned locators with that prefix.

Internal Maps

- As part of its attributes, a node can have internal maps.
- Given a map, a router can obtain a more detailed map by substituting one of the map's nodes by one of that node's internal maps. This process can be continued recursively.
- A node's "detailed map" gives more information about the region of the network represented by the original node. Typically, it is closer to the physical realization of the network than the original node.
- The nodes of this map can themselves have detailed maps.

Other Node Attributes

- *Transit Connectivity*: This attribute specifies the services available between the heads of arcs arriving to that node and the heads of arcs leaving that node.

- *Inbound Connectivity*: This attribute represents connectivity from arcs impinging on the node to the inside of the node.

- *Outbound Connectivity*: This attribute represents connectivity from the inside of the node to the head of arcs leaving the node.

These attributes have locators that are prefixed by the node's locator.

Forwarding Modes

Nimrod supports four forwarding modes:

1. Connectivity Specification Chain (CSC) mode: packets carry a list of connectivity specification locators of contiguous BTEs;
2. Connectivity Specification Sequence (CSS) mode: packets carry a list of connectivity specification locators of non-necessarily contiguous BTEs;
3. Flow mode: the packet header includes a path-id that indexes state that has been previously set up in routers along the path;
4. Datagram mode: the packet header carries source and destination locators.