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A TECHNICAL SURVEY OF NETWORK ROUTERS

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ABSTRACT

Switches create a network. Routers connect networks. A router links computers to the Internet, so users can share the connection. A router acts as a dispatcher, choosing the best path for information to travel so it's received quickly. Over last 20 plus years, many Routing Protocols, strategies, Algorithms & Architectures have evolved & become popular. Hence, it becomes imperative to enlist all these & its technical feature set. This technical survey paper, being part of my Research work, is a serious effort in that direction.

KEYWORDS :*Routing, Circuit Switching, Packet Switching, Network Topology, NOC Routers, Router Architectures, Routing Algorithms.*

INTRODUCTION :

Routing is the process of selecting best paths in a network. In the past, the term routing also meant forwarding network traffic among networks. However, that latter function is better described as forwarding. Routing is performed for many kinds of networks, including the telephone network (circuit switching), electronic data networks (such as the Internet), and transportation networks. This article is concerned primarily with routing in electronic data networks using packet switching technology[1].

In packet switching networks, routing directs packet forwarding (the transit of logically addressed network packets from their source toward their ultimate destination) through intermediate nodes. Intermediate nodes are typically network hardware devices such as routers, bridges, gateways, firewalls, or switches.

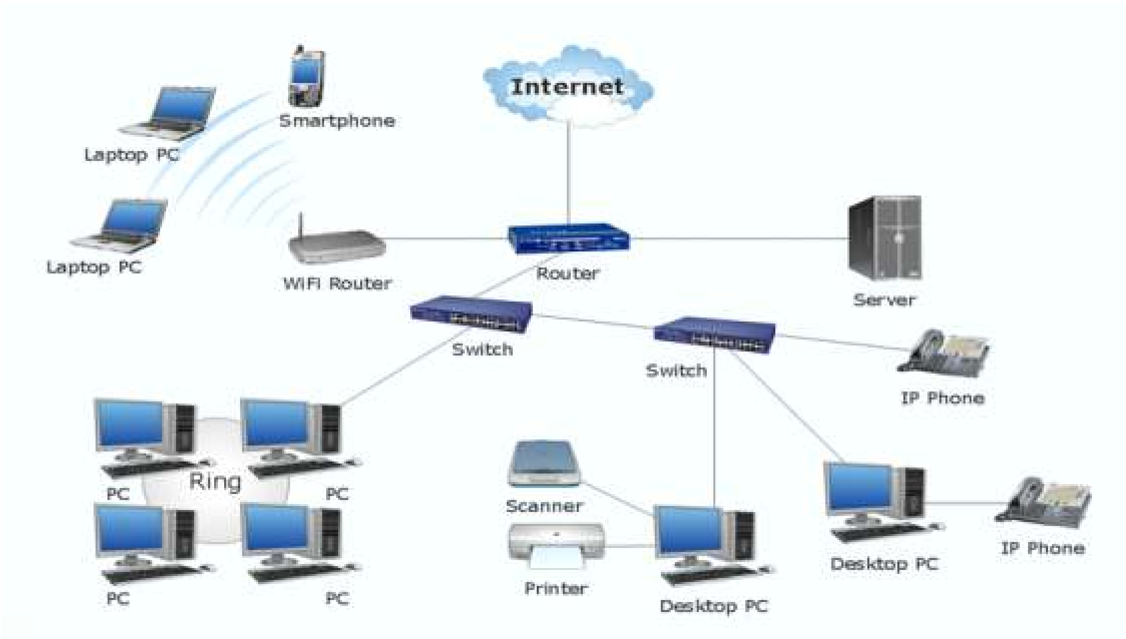

Fig 1: Present day Complex Network based System

General-purpose computers can also forward packets and perform routing, though they are not specialized hardware and may suffer from limited performance. The routing process usually directs forwarding on the basis of routing tables, which maintain a record of the routes to various network destinations.

Thus, constructing routing tables, which are held in the router's memory, is very important for efficient routing. Most routing algorithms use only one network path at a time. Multipath routing techniques enable the use of multiple alternative paths.

NETWORK TOPOLOGY

Topology can also be defined as the geometrically interconnection pattern by which the stations (nodes/computers) are connected using suitable transmission media (which can be point-to-point and broadcast).

Topology refers to the way in which the network of computers is connected. Each topology is suited to specific tasks and has its own advantages and disadvantages.

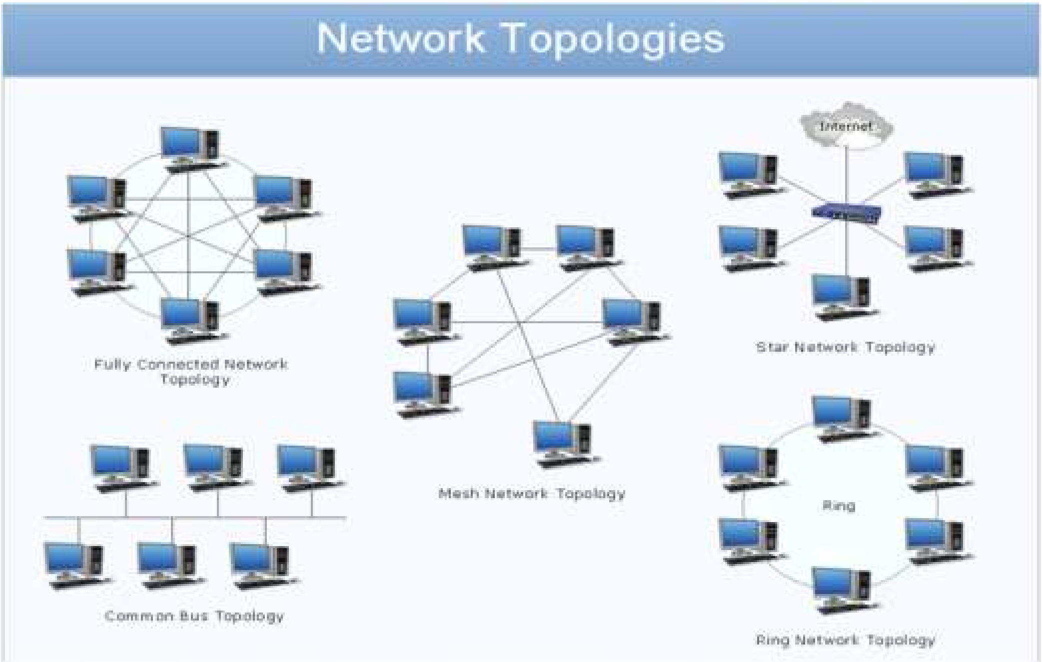

Fig2. Popular Network Topologies[2]

Various commonly used topologies are:

o Mesh
o Bus
o Star
o Ring
o Tree
o Unconstrained

The choice of topology is dependent upon type and number of equipment being used, planned applications and rate of data transfer required, response time, and cost[3].

Network - History & Evolution

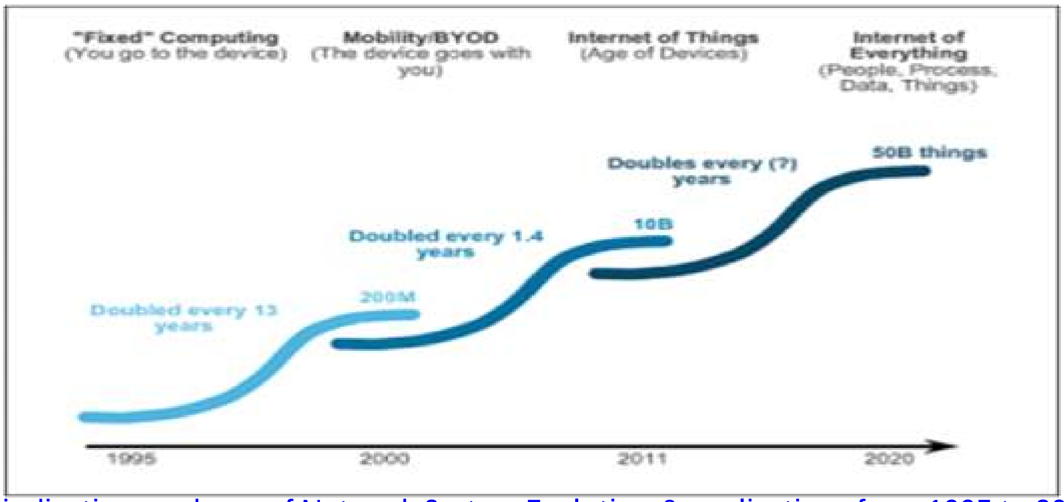

Fig.3 indicating roadmap of Network System Evolution & applications from 1995 to 2020

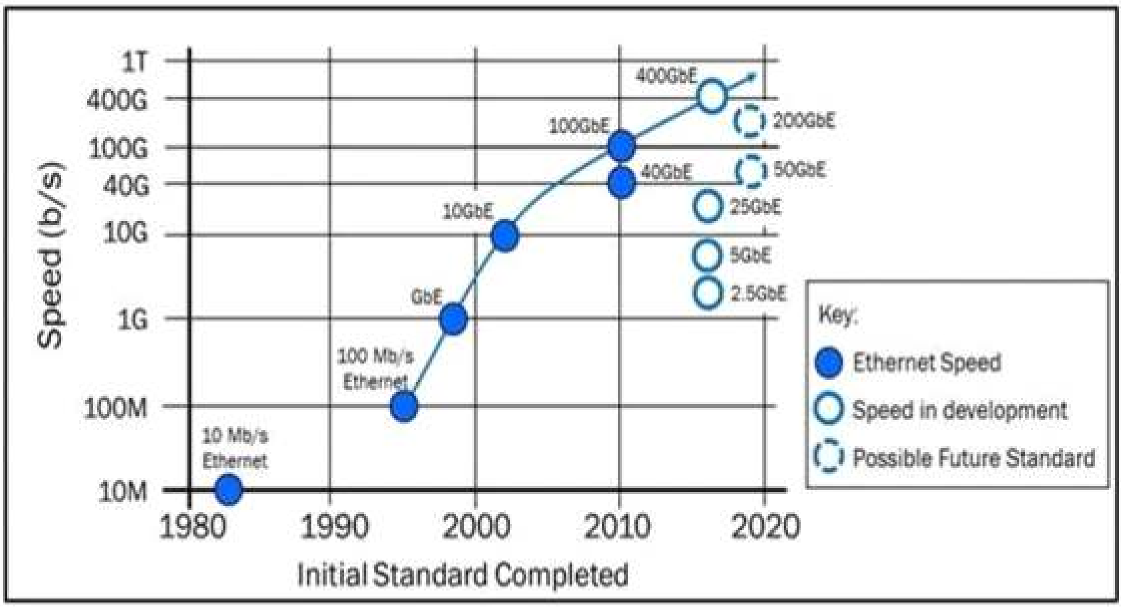

Fig4. Ethernet speed road map

Routers

A router consists of a computer networking device that determines the next network point to which a data packet has to be forwarded on its way to its destination. Fig.1 shows a present day Complex Network based System.

A router[a] is a networking device that forwards data packets between computer networks. Routers perform the "traffic directing" functions on the Internet. A data packet is typically forwarded from one router to another through the networks that constitute the internetwork until it reaches its destination node.[1]

A router is connected to two or more data lines from different networks (as opposed to a network switch, which connects data lines from one single network). When a data packet comes in on one of the lines, the router reads the address information in the packet to determine its ultimate destination. Then, using information in its routing table or routing policy, it directs the packet to the next network on its journey. This creates an overlay internetwork.

NOC Routers

The design and implementation of a router requires the definition of a set of policies to deal with packet collision, the routing itself, and so on. A NoC router is composed of a number of input ports (connected to shared NoC channels), a number of output ports (connected to possibly other shared channels), a switching matrix connecting the input ports to the output ports, and a local port to access the IP core connected to this router. As an example, the interface of the RaSoC router is presented in Figure 5.

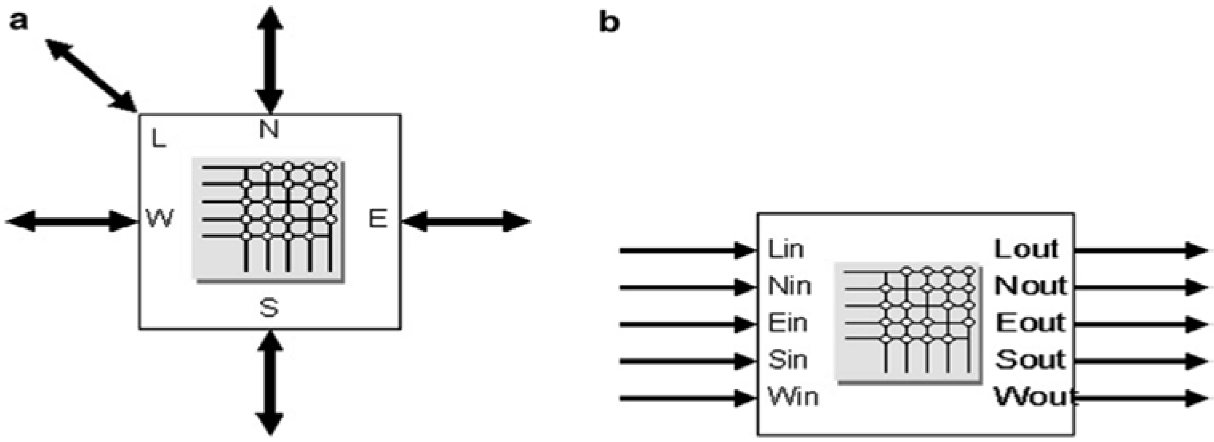

Fig 5.Interface views of a typical router (a) functional view, (b) architectural view

In addition to this physical connection infrastructure, the router also contains a logic block that implements the flow control policies (routing, arbiter, etc.) and defines the overall strategy for moving data though the NoC[4].

Early routers were essentially general purpose computers. Today, high-performance routers resemble supercomputers

– Exploit parallelism

– Special hardware components

Router Architectures – Generations:

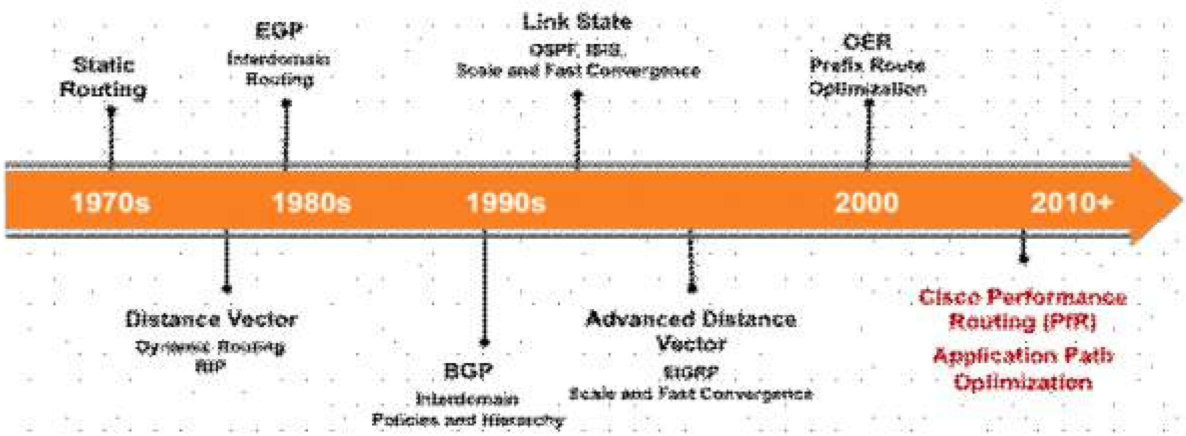

Fig6. Evolution of Router Architectures[5]

Evolution of Router Architectures

- Until 1980s (1st generation): standard computer
- Early 1990s (2nd generation): delegate to interfaces
- Late 1990s (3rd generation): Distributed architecture
- Today: Distributed over multiple racks

1st Generation Routers

- This architecture is still used in low-end routers
- Arriving packets are copied to main memory via direct memory access (DMA)
- Interconnection network is a back-plane (shared bus)
- All IP forwarding functions are performed in the central processor.
- Routing cache at processor can accelerate the routing table lookup.

Drawbacks:

– Forwarding Performance is limited by CPU
– Capacity of shared bus limits the number of interface cards that can be connected

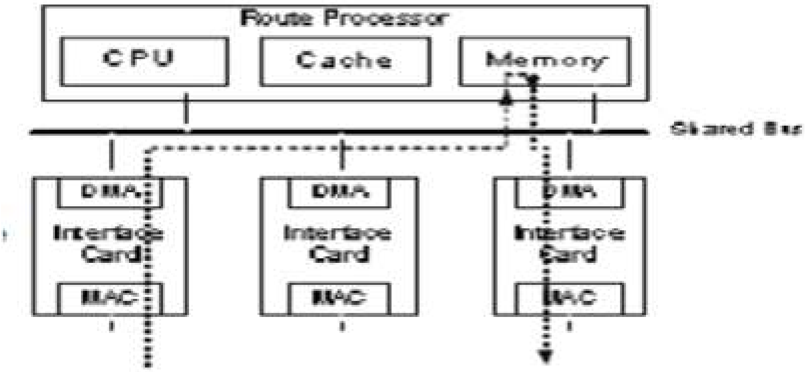

Fig 7. 1st Generation Router

2nd Generation Router

- IP forwarding is done by separate components (Forwarding Engines)

Forwarding operations:

1. Packet received on interface: Store the packet in local memory. Extracts IP header and sent to one forwarding engine
2. Forwarding engine does lookup, updates IP header, and sends it back to incoming interface
3. Packet is reconstructed and sent to outgoing interface

3rd Generation Architecture

- Interconnection network is a switch fabric (e.g., a crossbar switch)
- Distributed architecture:
– Interface cards operate independent of each other
– No centralized processing for IP forwarding
- These routers can be scaled to many hundred interface cards and to aggregate capacity of > 1 Terabit per second

Router Operations:

A router has two stages of operation called planes:[4]

• Control plane: A router maintains a routing table that lists which route should be used to forward a data packet, and through which physical interface connection. It does this using internal pre-configured directive, called static routes, or by learning routes using a dynamic routing protocol. Static and dynamic routes are stored in the Routing Information Base (RIB). The control-plane logic then strips the

RIB from non essential directives and builds a Forwarding Information Base (FIB) to be used by the forwarding-plane.

• Forwarding plane: The router forwards data packets between incoming and outgoing interface connections. It routes them to the correct network type using information that the packet header contains. It uses data recorded in the routing table control plane[6].

ROUTING OBJECTIVES:

- Responsible for correctly and efficiently routing packets or circuits from the source to the destination
- Choice of a routing algorithm depends on trade-offs between several potentially conflicting metrics

?minimizing power required for routing
?minimizing logic and routing tables to achieve a lower area footprint
?increasing performance by reducing delay and maximizing traffic utilization of the network
?improving robustness to better adapt to changing traffic needs
Routing schemes can be classified into several categories
?Static or Dynamic routing
?Distributed or Source routing
?Minimal or non-Minimal routing

Static Routing

— May be suitable on small networks
— Administration intensive as changes have to be made on each router
— Commonly used for default routing
• 0.0.0.0/0 → Next Hop Router

Dynamic Routing Protocol Types

— Distance Vector
• Routing Information Protocol(RIP)
• Interior Gateway Routing Protocol(IGRP)
• Enhanced Interior Gateway Routing Protocol(EIGRP)
— Link State
• Open Shortest Path First(OSPF)
• Intermediate System to Intermediate System(ISIS)
— Path Vector
— Hierarchical routing
— Broadcast routing
— Multicast routing
— Border Gateway Protocol(BGP)

Switching strategy defines the way resources are allocated to the packets transfered across the chip.Two common strategies:
?Circuit Switching
?Packet Switching

Router Protocols:

- Interior Routing Protocol (IRP)
- Exterior Routing Protocols(ERP)

Interior Routing Protocol (IRP)

- Used within an autonomous system
- Used within an area of administrative contro
- IRP passes routing information between routers within AS

o Need exchange of info among the routers only in AS[7]

- Different autonomous systems may have different IRP mechanisms like

o Static
o RIP
o OSPF
o EIGRP
o ISIS

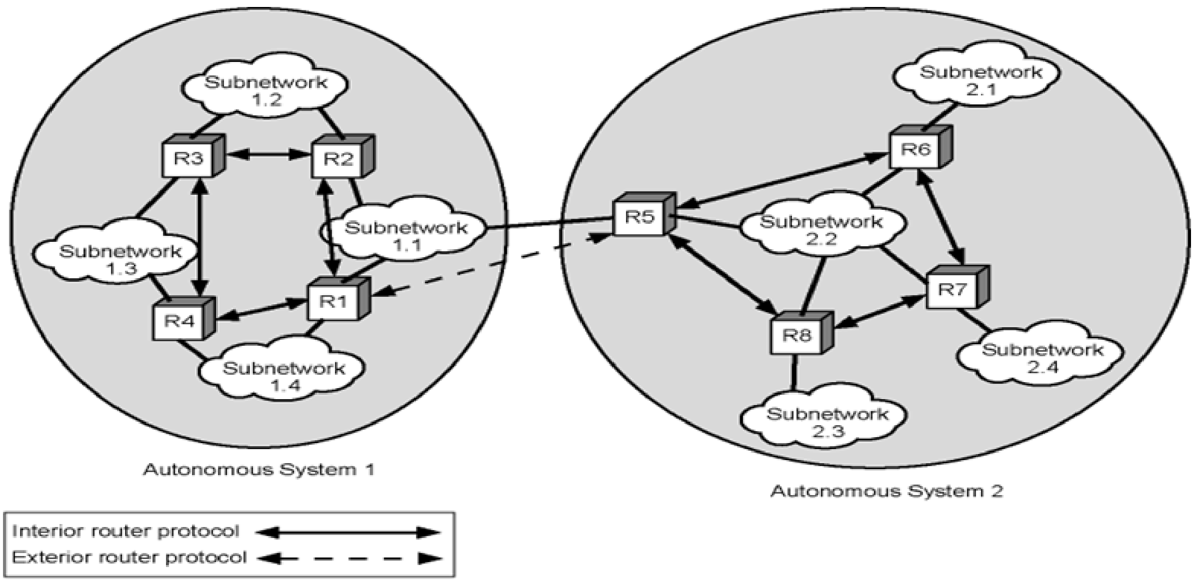

Fig8. IRP & ERP illustration

Exterior Routing Protocol (ERP)

— Used between autonomous systems
— Used to peer with networks in which you have no administrative control

- Autonomous systems need to talk to each other

— Need minimum information from other connected AS
— A few routers in each AS must talk
— Use Exterior Routing Protocol (ERP)

- Again, a concept

— ERP does not deal with details within source and target AS
— BGP[8]

Routing algorithms

The Routing algorithm is the logic that selects one output port to forward a packet that arrives at the router input. This port is selected according to the routing information available in the packet header. There are several possible routing algorithms that can be used in a NoC, each one leading to different trade-offs between performance and cost.

Routing Algorithms – examples

Deterministic routing
The route is determined solely by source and destination locations.

Arithmetic routing
The destination address of the incoming packet is compared with the address of the switch and the packet is routed accordingly. (Relative or Absolute addresses)[8]

Source based routing
The source determines the route and builds a header with one directive for each switch. The switches strip off the top directive.

Table-driven routing
Switches have routing tables, which can be configured.

Adaptive routing
The route can be adapted by the switches to balance the load.

Minimal routing
It allows only shortest paths

Non-minimal routing
It allows even longer paths

Algorithm Types

Routing algorithms can be classified by type. Key differentiators include these:
• Static v/s dynamic
• Single-path v/s multipath
• Flat v/s Hierarchical
• Host-intelligent v/s router-intelligent
• Intra-domain v/sInter-domain
• Link-state v/s distance vector

Static v/s Dynamic

Static routing algorithms are hardly algorithms at all, but are table mappings established by the networkadministrator before the beginning of routing. These mappings do not change unless the networkadministrator alters them. Algorithms that use static routes are simple to design and work well inenvironments where network traffic is relatively predictable and where network design is relativelysimple.

Because static routing systems cannot react to network changes, they generally are considered unsuitablefor today's large, constantly changing networks. Most of the dominant routing algorithms today aredynamic routing algorithms, which adjust to changing network circumstances by analyzing incomingrouting update messages.

If the message indicates that a network change has occurred, the routingsoftware recalculates routes and sends out new routing update messages. These messages permeate thenetwork, stimulating routers to rerun their algorithms and change their routing tables accordingly[9].

Dynamic routing algorithms can be supplemented with static routes where appropriate. A router of lastresort (a router to which all unroutable packets are sent), for example, can be designated to act as arepository for all unroutable packets, ensuring that all messages are at least handled in some way.

Single-Path v/s Multipath

Some sophisticated routing protocols support multiple paths to the same destination. Unlike single-pathalgorithms, these multipath algorithms permit traffic multiplexing over multiple lines. The advantagesof multipath algorithms are obvious: They can provide substantially better throughput and reliability.This is generally called load sharing.

Flat v/s Hierarchical

Some routing algorithms operate in a flat space, while others use routing hierarchies. In a flat routingsystem, the routers are peers of all others. In a hierarchical routing system, some routers form whatamounts to a routing backbone. Packets from non-backbone routers travel to the backbone routers, wherethey are sent through the backbone until they reach the general area of the destination.At this point, theytravel from the last backbone router through one or more non-backbone routers to the final destination.

Routing systems often designate logical groups of nodes, called domains, autonomous systems, or areas.Inhierarchical systems, some routers in a domain can communicate with routers in other domains, whileothers can communicate only with routers within their domain. In very large networks, additionalhierarchical levels may exist, with routers at the highest hierarchical level forming the routing backbone.

The primary advantage of hierarchical routing is that it mimics the organization of most companies andtherefore supports their traffic patterns well. Most network communication occurs within small companygroups (domains). Because intra-domain routers need to know only about other routers within theirdomain, their routing algorithms can be simplified, and, depending on the routing algorithm being used,routing update traffic can be reduced accordingly.

Host-Intelligent v/s Router-Intelligent

Some routing algorithms assume that the source end node will determine the entire route. This is usuallyreferred to as source routing. In source-routing systems, routers merely act as store-and-forward devices,mindlessly sending the packet to the next stop.

Other algorithms assume that hosts know nothing about routes. In these algorithms, routers determinethe path through the internetwork based on their own calculations. In the first system, the hosts have therouting intelligence. In the latter system, routers have the routing intelligence[10].

Intra-Domain v/s Inter-Domain

Some routing algorithms work only within domains; others work within and between domains. Thenature of these two algorithm types is different. It stands to reason, therefore, that an optimalintra-domain routing algorithm would not necessarily be an optimal inter-domain routing algorithm.

Link-State v/s Distance Vector

Link-state algorithms (also known as shortest path first algorithms) flood routing information to allnodes in the internetwork. Each router, however, sends only the portion of the routing table that describesthe state of its own links. In link-state algorithms, each router builds a picture of the entire network in its routing tables.

Distance vector algorithms (also known as Bellman-Ford algorithms) call for eachrouter to send all or some portion of its routing table, but only to its neighbors. In essence, link-statealgorithms send small updates everywhere, while distance vector algorithms send larger updates only toneighboring routers. Distance vector algorithms know only about their neighbors.

Because they converge more quickly, link-state algorithms are somewhat less prone to routing loops thandistance vector algorithms. On the other hand, link-state algorithms require more CPU power andmemory than distance vector algorithms. Link-state algorithms, therefore, can be more expensive toimplement and support. Link-state protocols are generally more scalable than distance vector protocols.[12]

Approaches to Routing

–Distance vector
–Link-state
–Path-vector

Latest Routing algorithms

– Least cost
– Dijkstra's
– Bellman-Ford routing

Popular Routing Algorithms:

• Shortest Path Routing
• Flooding
• Distance Vector Routing
• Link State routing
• Hierarchical routing
• Broadcast routing
• Multicast routing[13]

Classification of Routing Algorithms:

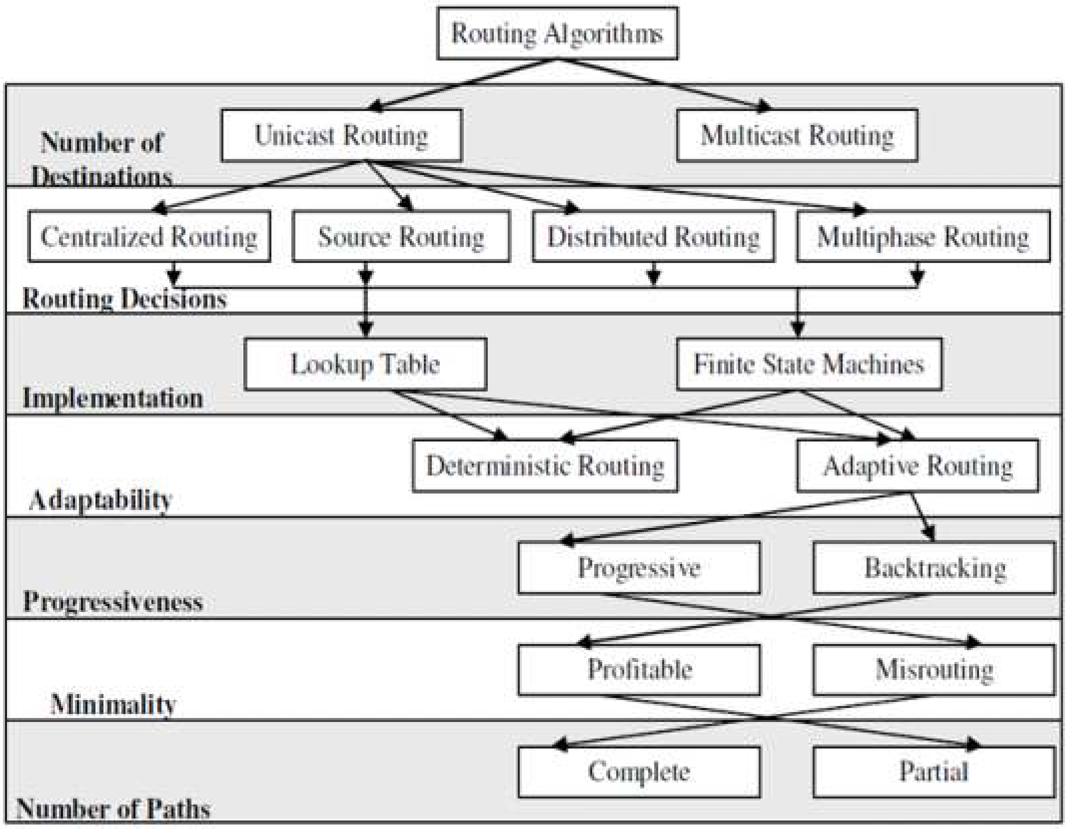

Fig 9: Routing Algorithms classification

CONCLUSION

After exhaustive technical survey, I have drafted this technical survey paper on NETWORK ROUTERS to cover all the basic aspects of Routing, Router architectures & Routing Algorithms. As a part of my Research work, I plan to experiment these popular Routing Strategies, protocols, Architectures& Algorithms etc. and arrive at the best strategy for various Router Applications on FPGA Hardware platform.

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