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Digital Cross Connect Systems [DCS] – a Technology Survey, Key Challenges, Architectures & Applications

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***Abstract*—In this Survey paper on Digital cross connect Systems, we have done exhaustive Technology survey covering the Digital Switching key challenges, Switching tree classifications, DCS switch, non blocking & hybrid switch, DCS - evolution, architecture, types & applications, case studies etc. as a part of my ongoing Research work on DCS.**

***Index Terms*— DCS, Evolution of the Digital cross-connect, application, buffered crossbar, arbitration.**

I. Digital Switching - Key Challenges

Switches are the devices which creates temporary connections between two stations. High Bandwidth applications compulsorily require high speed switches. Digital switches are meant to handle digital signals and provide communication between the end stations.

- Technical challenges – size of the conversion task
    - Analogue equipment (transmitters) to be replaced with digital
    - New networks may be required [2]
    - New frequency plan:
        - new frequencies for many transmitters (require new antennas)
        - may result in changes of coverage
    - Simulcast:
        - spectrum is shared with analogue television;
        - analogue services must be protected during the transition
        - Cross-border issues: different time schedules in different countries
        - Integrity
        - Compatibility with new technologies
    - Scalability
    - Reliability
    - Cost
    - Throughput

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II. DIGITAL SWITCHING TREE

The below fig.1 shows popularly used SWITCHING TREE classification, Switching methods & techniques. Fig 2 & 3 depicts Segregated & Integrated transport switching networks [1]

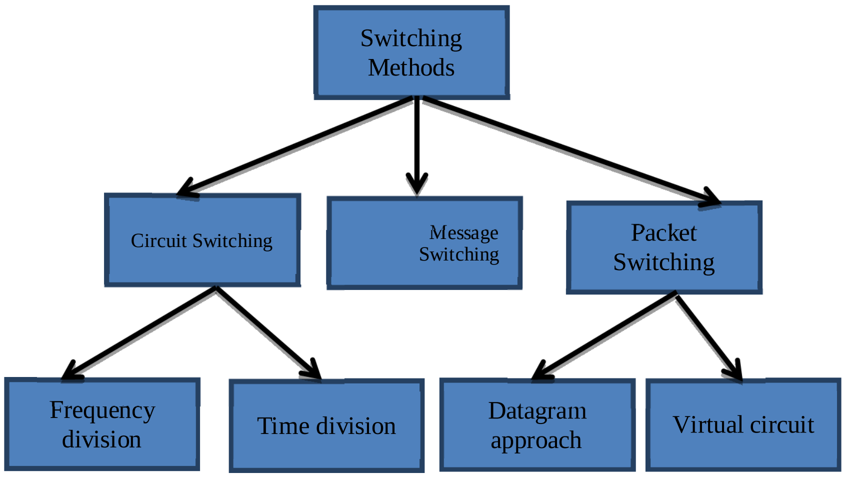

Fig.1: Switching Tree

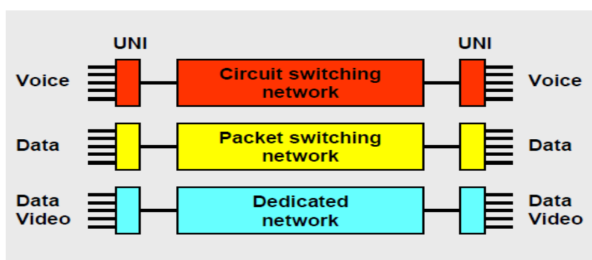

Fig 2: Segregated transport

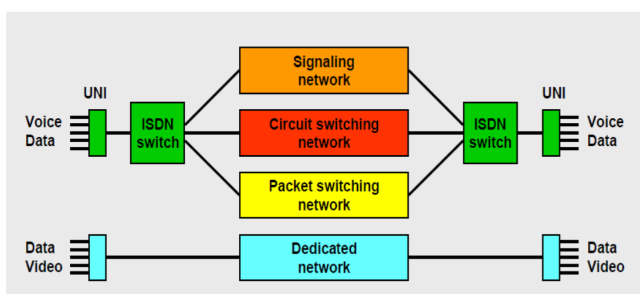

Fig 3: Integrated transport

Digital cross-connect (DCS) modulates low frequency TDM bits into high frequency TDM signals. It is used for building up applications related to switching, traffic management, network failure and automated back up switching.

DCS are very compact and high density systems which supports a wide range of applications. DCS are circuit switches and not packet switches and circuits must be designed to store and switch data that persist in a network for longer duration. A DCS device provides "grooming" of telecommunication traffic and supports

greater flexibility and redundancy in case of network failure. Modern DCS operates at higher data rates applications like SONET as well as lower data rates applications like T-carrier.
The advancement of technology has allowed digital cross-connect systems to evolve from narrowband grooming and test applications to cross- connection of larger network signals in wideband and broadband frequency domains.

A. The Evolution of the Digital cross-connect [refer Figure 4]

- DCS traces its history to 1976, there was intent to utilize emerging digital technology to create new switching systems for the local telecom offices.
- In 1987, digital cross-connects phased out the older manual switches.
- In 1990,DCS found its application in fiber optic Synchronous Optical Network (SONET).

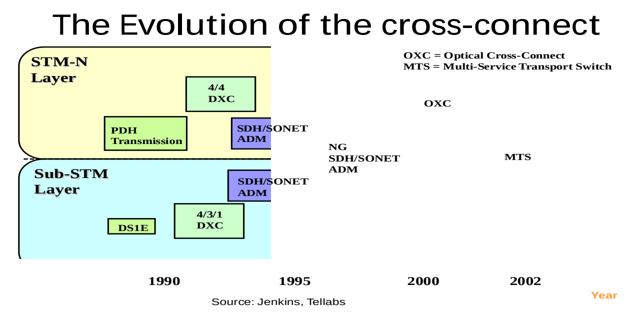

Figure 4: Evolution of the Digital cross-connect

III. DIGITAL CROSS CONNECT SWITCH

Owing to its simplicity and non-blocking capability crossbar switching fabric is very popular architecture for high speed switches.

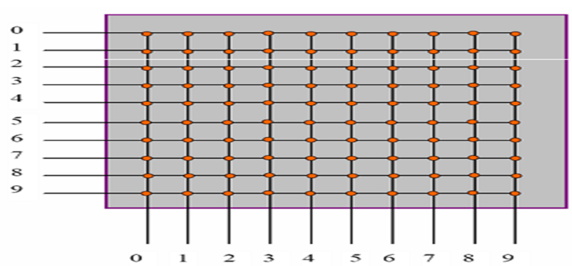

Fig 5 Digital cross bar switch [3]

It is basically crossbar matrix which was earlier used in an analog environment. Due to the development of semiconductor gates it has been well accepted in the digital domain. The cross point can be enabled or disabled by a control unit. This structure is strictly non blocking in nature. DCS shown in figure 4 has been used worldwide for last 20 years to manage variety of protocols and data rates efficiently in central offices and remote locations.
The switching technique here is space division switch where the paths of the signals are physically separated from each other. It makes use of a single cross point in order to establish a particular connection between input ports and output ports which results in better quality link. The time division switching utilizes the concept of time division multiplexing (TDM) in order to transmit speech samples from input to corresponding output ports. It allows the sharing of switching element by several speech circuits at the same time.

Hybrid switching combines the two technology to take advantage of both. This structure allows full availability by achieving both time slot interchange and switching of samples across the trunks [8]. Hence the popular hybrid combinations are:

- Time-Space switch
- Space-Time-Space switch
- Time-Space-Time switch

In order to improve the reliability of the system in case of fault and failure the last stage acts as a mirror image of the first stage. The selection of a particular architecture is based on various factors like cost, implementation complexity, blocking/non-blocking, manageability, testability, expandability and capacity of the network [8]. Single stage switch results in inefficient utilization of cross points. Due to increase in the number of cross points with the increment in attached stations, a multistage switch has been developed. A multistage switch with lesser cross points utilizes the cross points efficiently and provides redundancy but at the same time it is blocking in nature.

A. Scalable Non Blocking switch

NXN scalable non blocking switches are used widely in most of the landline and mobile exchanges. Non blocking means the switching will always make a connection. Figure 6 shows a 3-stage non blocking switch which works on the following formula. No. of cross points is equal to N/n×nk +k×(N/n)2+N/n×nk=2N+k(N/n)2 [3]. Where K is the column number, n is the row number and N is the no. of inputs.

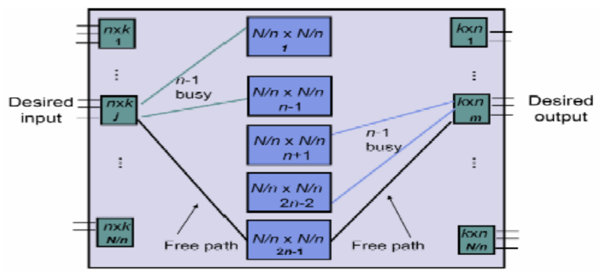

Fig 6: Non-blocking Switch [3]

B. Switching Architectures

- Shared Bus
- Shared Memory
- Crossbar

In shared bus architecture either a single bus or multiple (parallel) buses are used. It is easy to implement and considered as the simplest method to transfer data from input port to output port. In this switching architecture the output port normally contains the buffers. Shared memory architecture provides higher reliability without any crosstalk and are suitable for particular real time applications. Of the three basic switch architectures shared bus and shared memory architectures have physical and functional limitations on their scalability. Crossbar switches are highly scalable and are the obvious choice for high-performance switching.

IV. DCS ARCHITECTURES

All modules mentioned below are as per Figure 7 :

- **LM:** interfaces with the subscriber (analog side); check for off-hook/on-hook
- **IC:** format the signal before going to the switch
- **CP**: call processing, system recovery, storage, software upgrade, maintaining records, billing information, routing
- **NCP**: transfer routing information, switch setup, line module setup

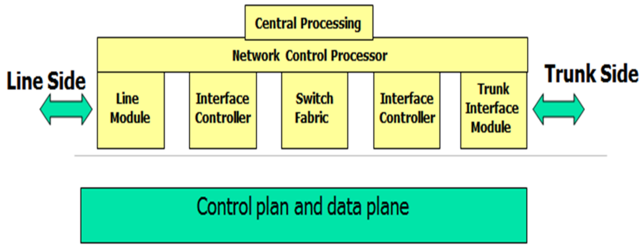

Fig 7: Basic DCS Architecture

Various implementations and architecture have been proposed for crossbar switches. Each design shows its own usefulness, Donghyun et. al proposes a crossbar switch architecture with adaptive bandwidth control [12]. A Buffered crossbar switch (BCS) without speedup has been proposed [14].

BCS shows a better performance compared to bufferless crossbar architecture [11]. BCS are popular because of their flexibility and distributed scheduling algorithm [13]. Distribution in scheduling reduces the arbitration complexity and presence of internal buffers drastically reduces the problem of output contention.

A. Buffered Crossbar Architectures

A basic Buffered Cross bar switch is shown in figure 8[4].

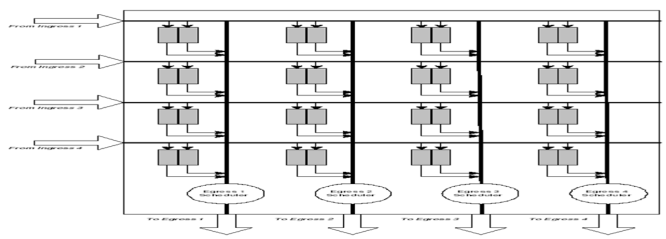

Fig 8: Buffered cross bar switch architecture

The addition of buffers at the cross points to reduce HOL blocking and hence increase throughput is referred to as buffered crossbar switch architecture. This scheme of placing buffers at the cross points instead of pure input buffering reduces the HOL blocking problem caused by output contention. With buffer memory placed at each cross point, the scheduler can maximize total throughput and keep many output ports as busy as possible by storing the input packets in buffer memory as shown in Figure 8[5].

B Advantages of Buffered-Crossbar Switch

- No need of memory speed-up since every memory should work at line speed.
- There is no contention between input and output ports since each one is using separate memories.
- There are distinct queues for input-output connections that is necessary for providing differentiated services between queues.

VI. DCS KEY APPLICATIONS

The Digital cross connect devices are the most compact and high-density systems of their kind, supporting a full range of services and applications such as

- High-speed data
- LAN connectivity and voice streaming
- Asynchronous Transfer mode (ATM) switch
- SONET network
- Synchronous digital hierarchy (SDH)
- Telecommunication traffic

- switching traffic from one circuit to other in the event of network failure
- Landline exchanges
- Broadband Exchanges
- Internet Hubs
- Mobile Switching for both Inter & Intra circle applications
- Voice, Data & Video switching capabilities
- Wireless switching or Wi-Fi[6]

A. DCS Applications in Mobile Communications

- Analog / Digital mobile traffic between mobile exchanges.
- Voice compression.
- Data traffic.
- LAN interconnection.
- Bandwidth optimization.

VII Digital Cross-Connect Systems In Traditional Network

In digital switching, in the place of manual cross connect system, digital cross connect system is used according to the requirements of network configurations. Basically DCS is digital switching matrix follow the call connection request of the signaling information. The main purpose of cross connect system is to rearrange the transmission circuit and test the circuit in both the directions. Generally, in two places manual cross connect systems are used i.e.

- Switching offices: the junction point between transmission facility and switching machines and
- The Wire centers: between feeder cables and distribution facility.

  Digital cross-connects are widely used in conjunction with central office telephone switches, as shown in Figure 9 and may be installed both before and/or after the switch. Cross connections are established via an administrative process and are semi-permanent. [6]

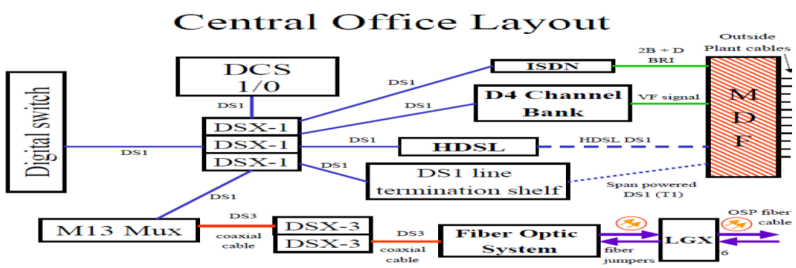

Fig 9: Digital Cross-Connect Systems in traditional network

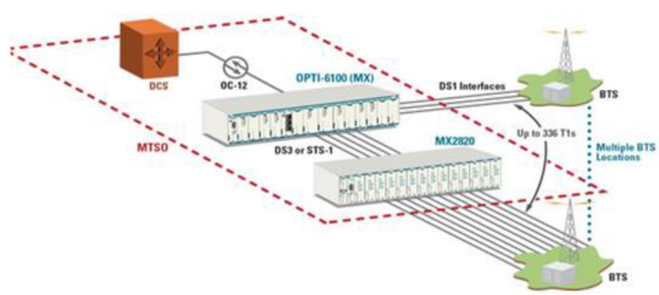

Fig 10: Digital Cross-Connect Systems in SDH

SDH Digital Access Cross Connect Systems (DCS) [Figure 10] provides valuable switching and grooming capabilities to a network, but they are often burdened by capacity limitations. Upgrading the existing equipment to remove the limitations can be expensive and portions of the network affected by capacity issues, such as sparsely populated areas, might not justify the upgrade costs associated with large traditional DCS platforms [7].

A .Digital Cross Connect System In Broadband

Broadband digital cross-connect systems deal with optical carrier rates. Broadband systems access Synchronous Transport Signals (STS-1) and switch SONET traffic at carrier-rate levels. A broadband digital cross-connect is designed to interconnect a large number of STS-1s. Broadband digital cross-connect systems typically handle transport transmission services that range in capacity from 50Mbps to 600Mbps. These systems can be used for the consolidation or segregation of bandwidth as shown in Figure 11.

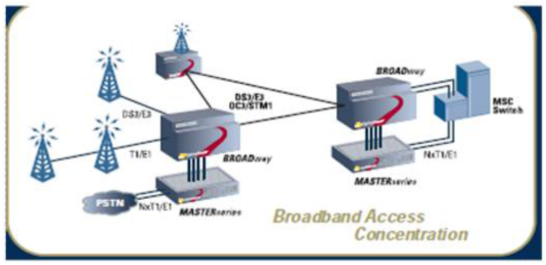

Fig 11: Digital Cross-Connect Systems in broadband

B. DCS - Key Features

- Efficient utilization of existing transmission bandwidth.
- Powerful NMS to manage large networks.
- The best flexibility for networking.
- Manageability
- Expandability [8]
- Higher service quality and hence higher customer satisfaction [9].

VII. DCS – TYPES

The three major blocks of DCS are I/O ports, Scheduler/arbiter and a crossbar fabric core. An scheduler/arbiter basically configures the crossbar by generating proper control signals and establishes a conflict free bath between input and output inlets. Hence in order to provide fairness among the various input ports and low latency and efficient design and implementation of arbiters are required.

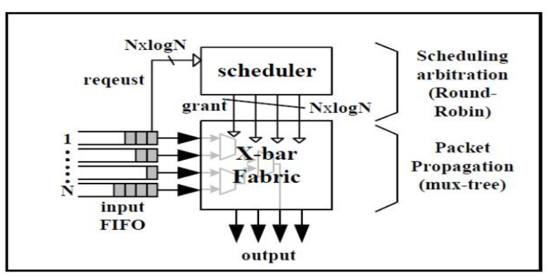

Fig 12: Round robin algorithm switching architecture

Most of the arbiters are implemented in round robin fashion which provides guaranteed fairness (figure 12) . For practical applications an arbiter must have the following properties high throughput, easy to implement, fast and starvation free.

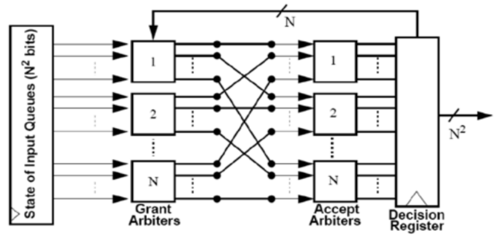

Fig 13: Implementation of iSLIP for an NXN switch

The scheduler (figure 10) is implemented using a modified form of the round robin arbitration scheme called iSLIP. This was chosen because it offered a balance between performance and ease of implementation [10] The scheduler was modified using folding to reduce the number of arbiters required to half the original number. The block diagram of the folded scheduler is shown in figure 13.

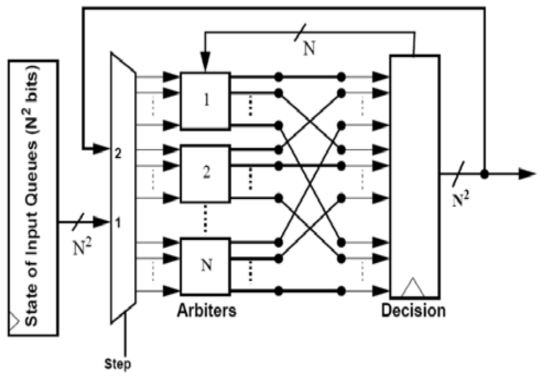

Fig 14: Arbiter and decision

VIII. CONCLUSION

Digital cross-connect systems are an integral part of today's modern telecommunications transport network. Digital cross connect System is a network facility used by enterprises to switch and multiplex low-speed voice and data signals onto high-speed lines and vice versa.
Markets at $260.7 million in 2011 are anticipated to reach $901.1 billion by 2018. A digital cross connects is presently used as standard in datacom and telecom.

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