Core Network

- Connects MAN networks together
- Requires high bandwidth technologies with long range passive operation
  - Transmission speed and distance without repeaters tend to be inversely proportional
    - 1Gbps Ethernet -> 80-150km in SM-fiber with ZX-transmitter
    - 10Gbps Ethernet -> 10-40km in SM-fiber with ZX-transmitter
- Typical medias are
  - Fiber (Single Mode)
  - Radio (Microwave, Satellite)

Core Network Technologies

- High bandwidth requirements
- Transmission speeds are jumping up with constant rate
  - 1995: 155Mbps (SDH/ATM)
  - 2000: 2.4Gbps (SDH)
  - 2004: 10 Gbps (SDH/Ethernet)
- 2000-2004 wavelength technologies brought a new means to increase capacity
  - DWDM
  - CWDM

Frame based multiplexing
- Irrespective of low layer functionality
  - Fiber/Radio
- Options today are
  - GMPLS
  - SDH
  - ATM
  - Ethernet
  - GFP
WDM

• Optical counterpart for Frequency Division Multiplexing

FDM

WDM

Carrier

WDM

• Effectively N fold increase of transmission capacity from the same fiber infrastructure
  - Wide band components are relatively more expensive than N times narrow band components
  - Individual lambdas can be used independently
    - Usage depends on transponder unit
      - Framing is in general from SDH (interface may be what ever)
        » STM-16 – 2.4Gbps
        » STM-64 – 10 Gbps = 10GbE
        » STM-256 – 40 Gbps = 40GbE

WDM

• Two operative versions
  - CWDM – Coarse Wavelength Division Multiplexing
    • Max 8 channels between (1470 - 1610nm with 20nm steps)
  - DWDM – Dense Wavelength Division Multiplexing
    • ITU Grid (100 Ghz resolution)
      - 50 channels between 1569.80nm to 1611.79nm
      - 50 channels between 1529.75nm to 1569.59nm
      - 50 channels between 1491.69nm to 1529.55nm

WDM

• DWDM
  - Narrow channel
    • Components need to be compensated for temperature effects
      - Expensive
    - More channels to choose from
      • nonlinearities of fibers can be avoided by selecting proper wavelengths

WDM

• CWDM
  - Wide channel
    • Component requirements are looser
      - Cheaper lasers and receivers
    - Less channels
      • Not suitable for long-haul networks
      • Suitable for MANs
WDM

- Can be used as link or network technology
  - Link technology
    - Multiplexers at the ends of the links
  - Network technology
    - Optical switching components
      - Optical delay lines
      - Wavelength conversion
      - Photonic switching

Pros:
- Protocol independent
- Virtual fiber
- Multiplexing different traffic through different wavelengths
- Similar failure protection than SDH networks (SDH framing)

Cons:
- Depending on system pay as you go may not be possible
  - The number of required channels need to be estimated for lifetime of systems
  - Not cost effective if capacity expansion is not immediately required

Frame Multiplexing

Synchronous multiplexing
- Fixed usage of resources

Asynchronous multiplexing
- Free usage of resources

Synchronous
- Fixed usage of resources
- Information does not need L2 addresses
- Wastes resources if communication is not CBR
- Easy to integrate
- SDH

Asynchronous
- Free usage of resources
- Information requires L2 addresses
- Does not waste resources
- Requires additional logics to control resource usage
- ATM, Ethernet
**SDH**

- Synchronous frame based multiplexing of transmitted signals
  - Link framing is done with 2430 byte frames
  - Generation interval is 125us -> reflects the original coding of speech with 8kHz sampling rate
    - Datarate = 155.52Mbps

- SDH hierarchy makes possible to use multiples and fractions of basic rate
  - Multiples are generated by injecting multiple (factor of four) link frames within time-slot
    - STM-1: 155.52 Mbit/s (basic rate)
    - STM-4: 622.08 Mbit/s (first multiplex)
    - STM-16: 2488.32 Mbit/s (second multiplex)
    - STM-64: 9953.28 Mbit/s (third multiplex)
  - Operation is byte synchronous
    - Timing of individual bytes in multiplex is same than in basic rate frame

- Fractions are generated by multiplexing different streams of content into individual frame
  - Several virtual containers destined to same or different points in network
  - Multiplexing is done with byte interleaving
SDH

- SDH supports also concatenation of resources
  - Old version – strict mode
    - Clear channel operation (small 'c' after the virtual container type)
    - All VC:s in different frames form a single bit stream
    - Not feasible in SDH networks
    - Feasible if SDH is used as a point to point link technology
  - New version – flexible mode
    - Concatenation is used only in edge devices
      - Supports SDH networks
      - Concatenated VC:s need not be with same speeds
        » Even over different fibers

SDH

- Terminal multiplexer
  - Responsible of taking non-SDH and lower rate SDH traffic in and interleave them in STM-N frames.
  - Vice versa on other end of the path
  - Each incoming traffic component has its own virtual container (routed separately within SDH network)

SDH

- Add-drop multiplexer
  - Basic component in ring type SDH networks
    - Most of traffic passes through the ADM on ring interfaces
    - Some traffic is taken out of ring and/or inserted into the ring

SDH

- Digital Cross Connect
  - Switches SDH traffic
    - Between fibers
    - From individual STM frame to other
    - Basic component on mesh type networks
**SDH**

- IP can not be used directly with SDH
  - Packet over Sonet (PoS) is method for delivering IP packets in SDH
    - Additional framing
      - IP packet into PPP-packet
      - PPP packet into HDLC frame
      - HDLC frame into SDH virtual container

**ATM**

- Asynchronous frame based multiplexing
- Capabilities for dynamic switching
  - Not only PVP’s or PVC’s
- Connection oriented
- Fixed packet structure
  - 5 bytes of headers
    - Addresses (VPI, VCI)
    - Packet content type (PT)
    - Priority (CLP)
    - Checksum (HEC)
  - 48 bytes of data
ATM

- Can be used
  - As is over the transmission media
    - Assumes low bit error ratio from the media
  - Over any other L2 protocol
    - Benefits from the error control of L2 media
- Why sensitivity to BER
  - Packet has no markers
    - Delineation is accomplished through state-machine which goes through packet bit by bit and looks header checksum matches
  - Sensitive to errors if high BER

48 byte content field is too big for voice communications
- Separate protocol layers to handle
  - Sub cell delineation
  - Timing
  - Sequencing
- Clear channel communication for video applications

48 byte content field is too little for data networks
- Fragmentation of data packets into multiple ATM cells
- Separate protocol layer to handle the fragmentation and reassembly of protocol packets

Framing options for IP traffic in ATM links:
- RFC2684: Multiprotocol Encapsulation over ATM Adaptation Layer 5 (Classical IP)
  - Uses LLC/SNAP encapsulation of traffic within ATM adaption layer 5
Framing options for IP traffic in ATM links:
- RFC2364: Point to Point Protocol over ATM
  - Uses in AAL5 frames either
    - raw PPP packets
    - PPP on LLC/NLPID packets

ATM network is from IP perspective
- NBMA network
  - Separate virtual connection between each and every router
    - Large number of connections and adjacencies in routing
  - Usually subinterface per connection

Pros:
- Easy capacity management
- Virtual short-cuts without routing
- MPLS ready
- Fault tolerant if ATM-level dynamic routing is used

Cons:
- Additional layer of technology
  - Not good for framing itself
- Expensive interfaces at routers
  - Subinterface structure in networked ATM

Technology has scaled to level where conventional core network technologies are
- STM-64 and 10GbE are the same
  - Even in optical interface level they are the same but ethernet is only 20% of the price
- STM-256 will be the base for 40GbE
- 1GbE is based on fiber channel but can be multiplexed in STM-16 networks by having two independent connections
Ethernet

- 10GbE
  - IEEE 802.3ae
  - Full duplex
  - Adjustable MAC speed
    - 10Gb in LAN
    - 9.29Gb in WAN
  - Optical media
  - SDH WAN Phy
  - 10Gb LAN Phy
- 1GbE
  - 802.3z
  - CSMA/CD + Full Duplex
  - Optical and copper media
  - Fiber channel Phy

Ethernet

- Possibility to build transparent LAN services
  - Majority of LAN networks are built with ethernet
  - Some applications benefit from the fact that ethernet headers are preserved
    - Possibility to have same IP subnet on both ends
    - WAN network is transparent for ethernet network
      - No PPP protocol in between SDH and Ethernet
    - VLANs provide separation of users within the core
      - Separate forwarding tables per customer
      - If customer has own VLANs so called aggregated VLAN can be used
        - Second VLAN header in packets within the core
- PoS way of doing things
  - Avoids protocol conversion between ethernet and PPP
- WAN ethernet way
  - Avoids protocol conversion between ethernet and PPP

Source: http://www.foundrynet.com/
Ethernet

- **Pros:**
  - Optimized for burst data services
  - No protocol conversion for interfacing with routers and LAN switches
  - Plug-and-play ideology in operation
- **Cons:**
  - Expensive and complicated to support the TDM voice and leased line services
  - Poor in trouble isolation and network recovery
    - Spanning tree operation takes tens of seconds to recover the networks
    - IEEE802.17 (Resilient Packet Ring) and BFD (Bi-directional Forwarding Detection) will eventually help this