Space Division Multiplexing (SDM)

A New Milestone in the Evolution of Fiber Optic Communication

GROUP MEMBERS:

1. SYED M.JEHANZEB JAFRI (16256)

2. ZEESHAN SAEED KHAN (14960)

3. SHAN ALI SYED (14924)

4. SAYED RASHID ASAD (16134)

5. M.NOMAN KHAN (16208)

6. MEHDI HUSSAIN (14961)

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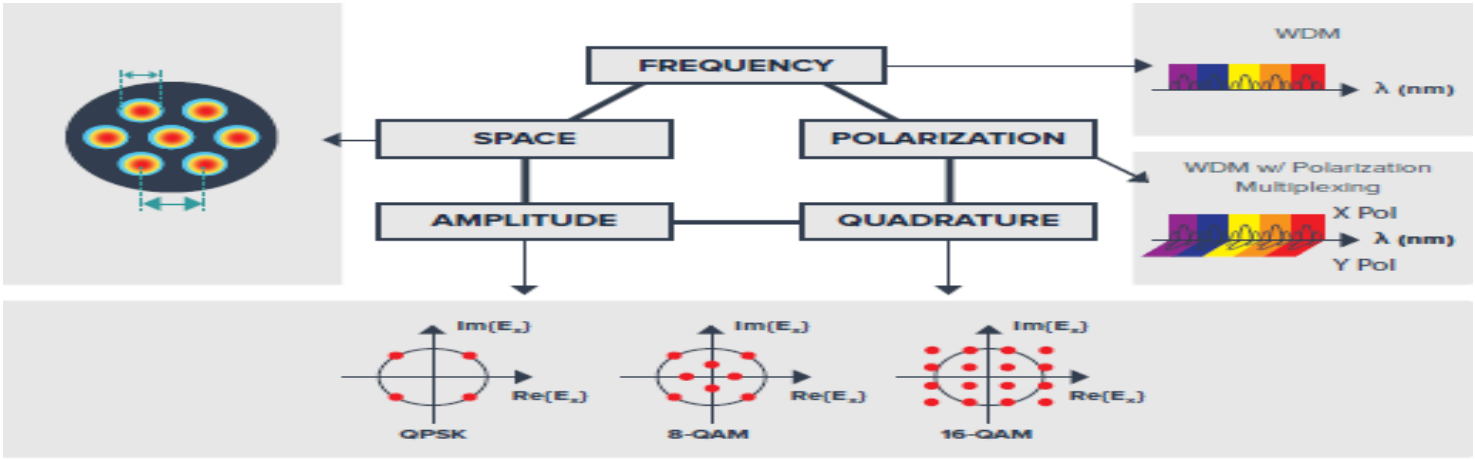
1. What is SDM?



- There are several possible methods for increasing transmission capacity over fixed bandwidth.
- These include modulation employing different amplitude levels, two orthogonal subcarriers and polarization.
- In fact, the only remaining unused dimension is Space.

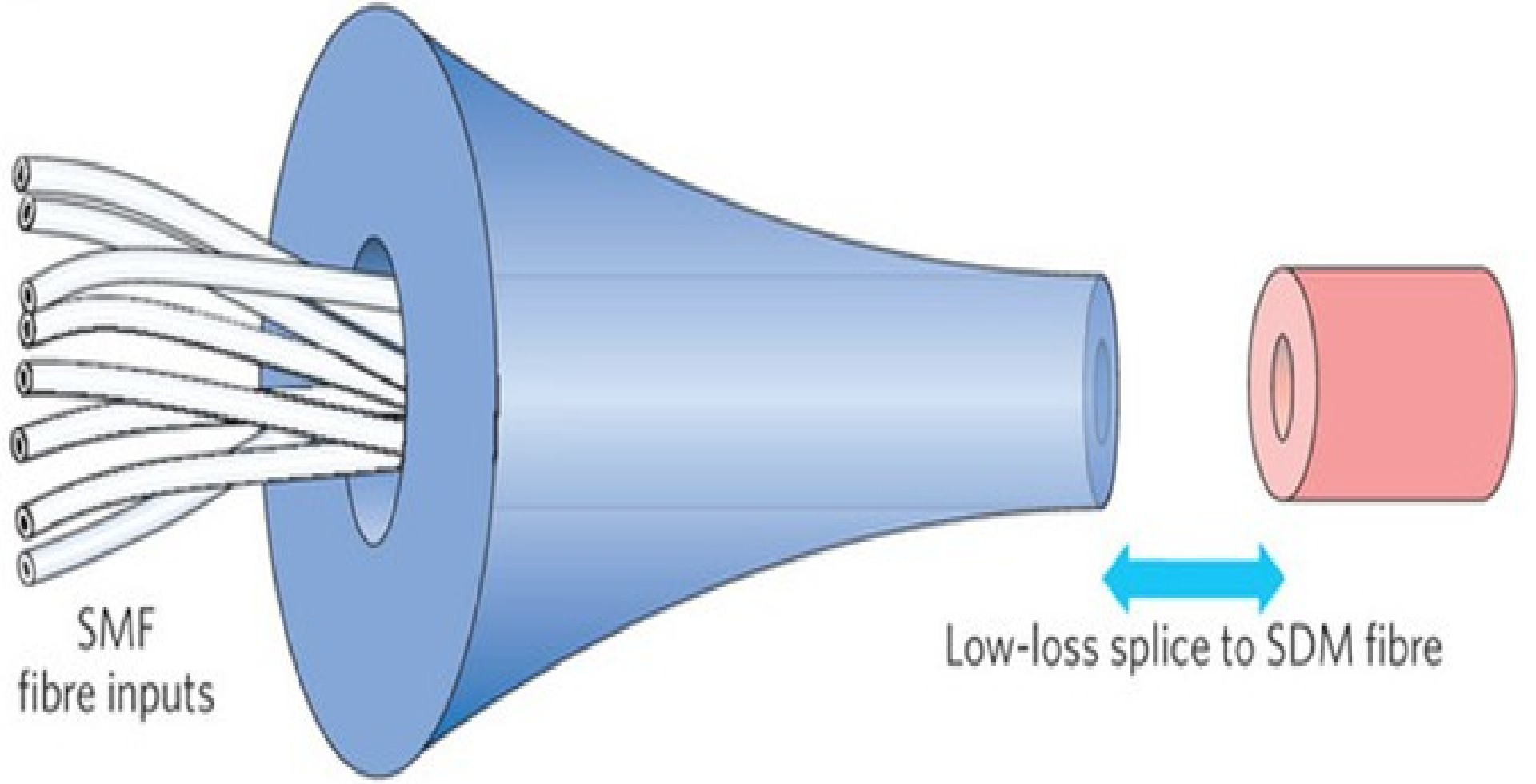
1. What is SDM?

- There are two basic strategies for achieving spatial separation within a fiber
- Multi-core and multi-mode operation.

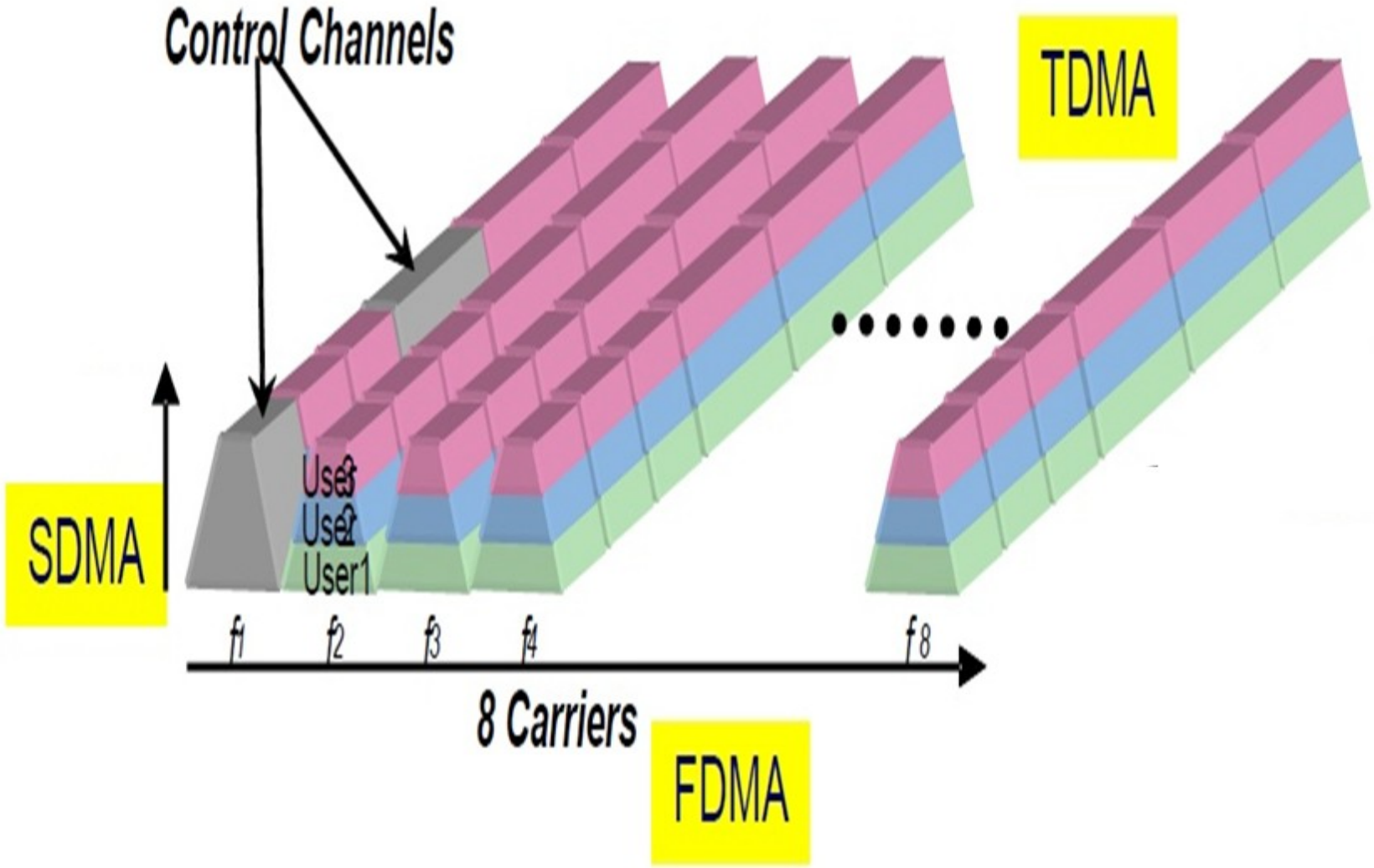
MULTICORE FIBER

- Multi-core fiber has several cores embedded in the fiber cladding.
- This causes crosstalk between them, which ultimately limits transmission performance.

1. MULTICORE FIBER TRANSMISSION

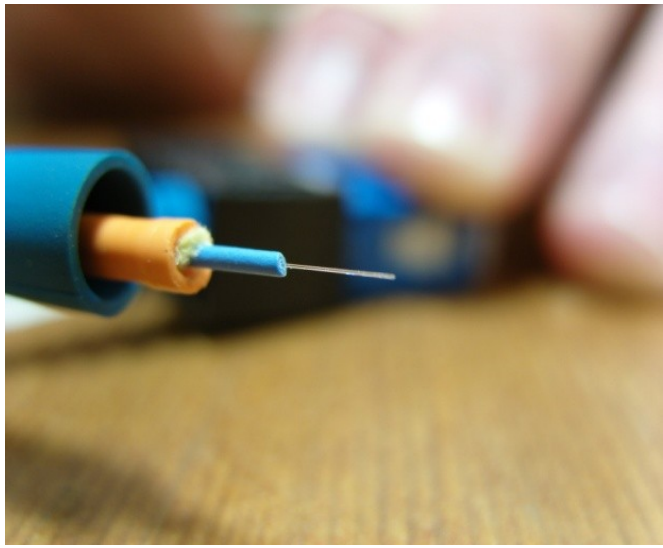


1. FREQUENCY REUSE in SDMA



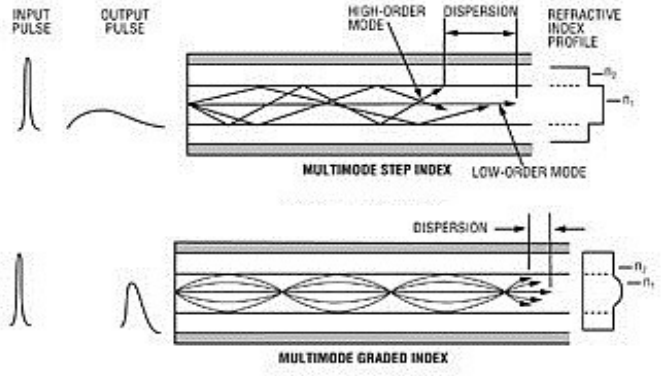
1. MULTICORE FIBER N MULTIMODE FIBER

- Multi-mode fiber ,propagation of seveal independent modes within a single core.



- The number of modes is determined by the core size and the refractive index of the fiber.

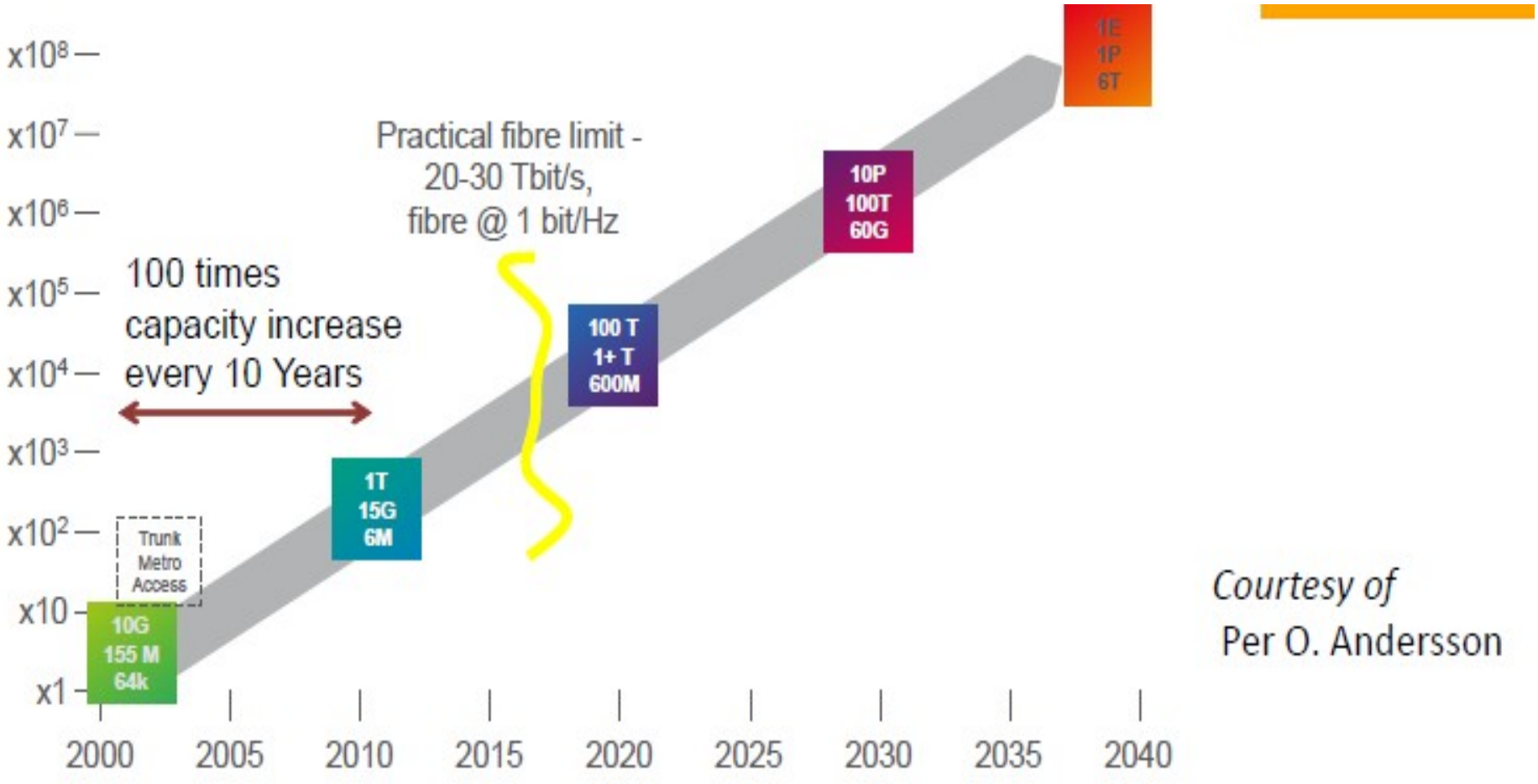
- Increasing the size of the core allows for more modes to be supported within the fiber.



1. What is SDM?

- SDM is straightforward solution to electro-optical bottleneck.
- In SDM, single fiber is replaced with multiple fibers used in parallel (e.g., electronic peak rate of OEO transceiver).
- SDM well suited for short-distance transmissions.
- SDM becomes less practical.
- More costly for increasing distances since multiple fibers need to be installed and operated.

Moore's Law for ever ... ?

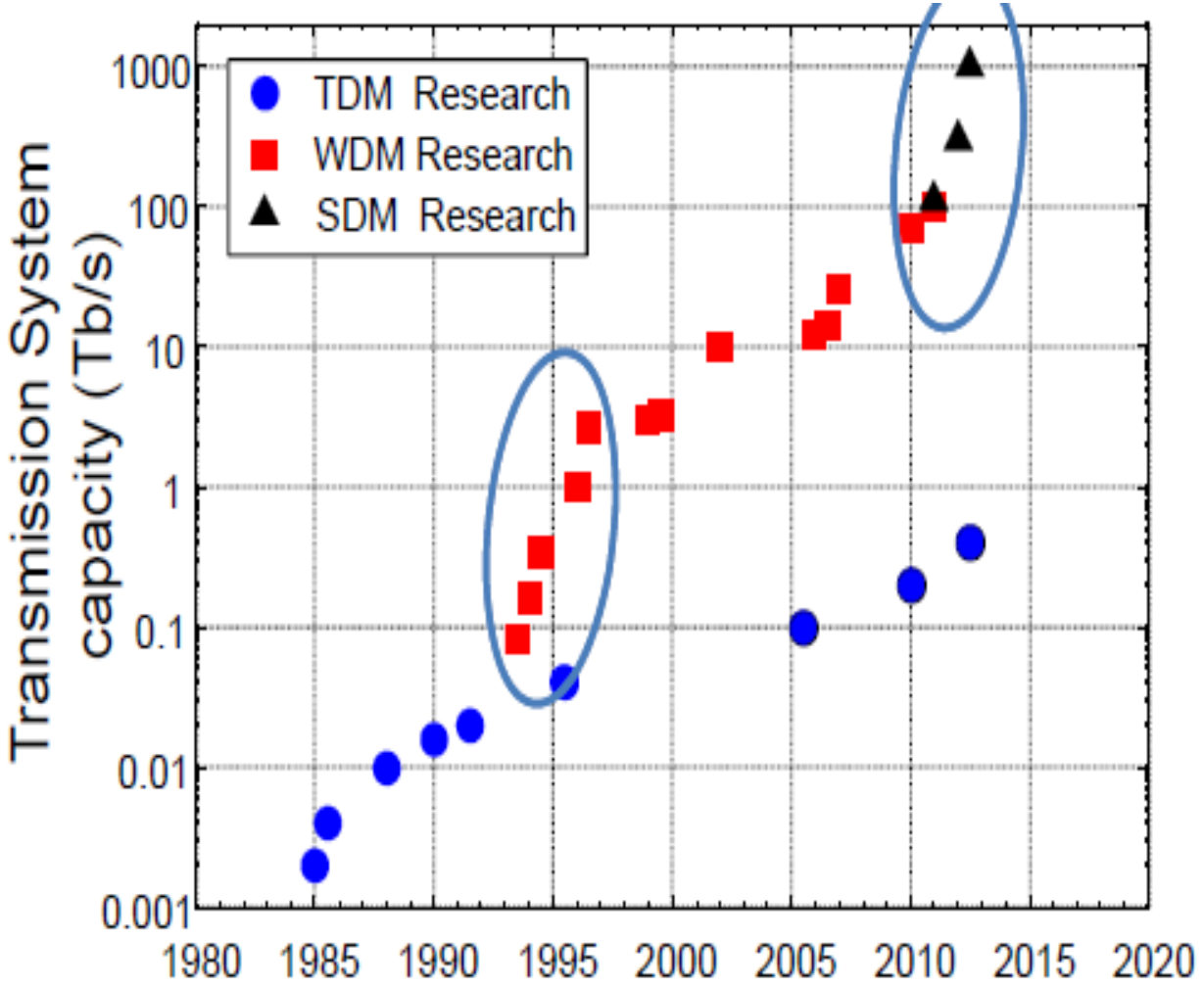


Rapid Progress For SDM

10 times increase in transmission capacity achieved with SDM in couple of years

Courtesy of

R.-J. Essiambre and R. W. Tkach



2. Features of SDM?

- Optical fibre transmission capacity increasing the number of spatial channels over a single fibre.
- High scalability is achieved by switching traffic at coarse granularities, e.g. fibre-to-core, core-to-core, core-to-fibre.
- SDM technologies and provide us with great means to achieve more system capacity,scalability and flexibility
- A capacity-distance product of 1 Eb/s-km (1 Pb/s x 1,000 km,)should be the next mile stone in SDM transmission technologies,

2. Features of SDM?

- This is one of the techniques that can be used for controlling the medium access for wireless networks.

- SDMA increases the capacity of the system and transmission quality by focusing the signal into narrow transmission beams.

- SDMA is never used in isolation i.e. it uses a combination of one or more other schemes such as TDM, FDM and CDM etc.

- SDMA requires careful choice of zones for each transmitter.

3. SDM and SDN

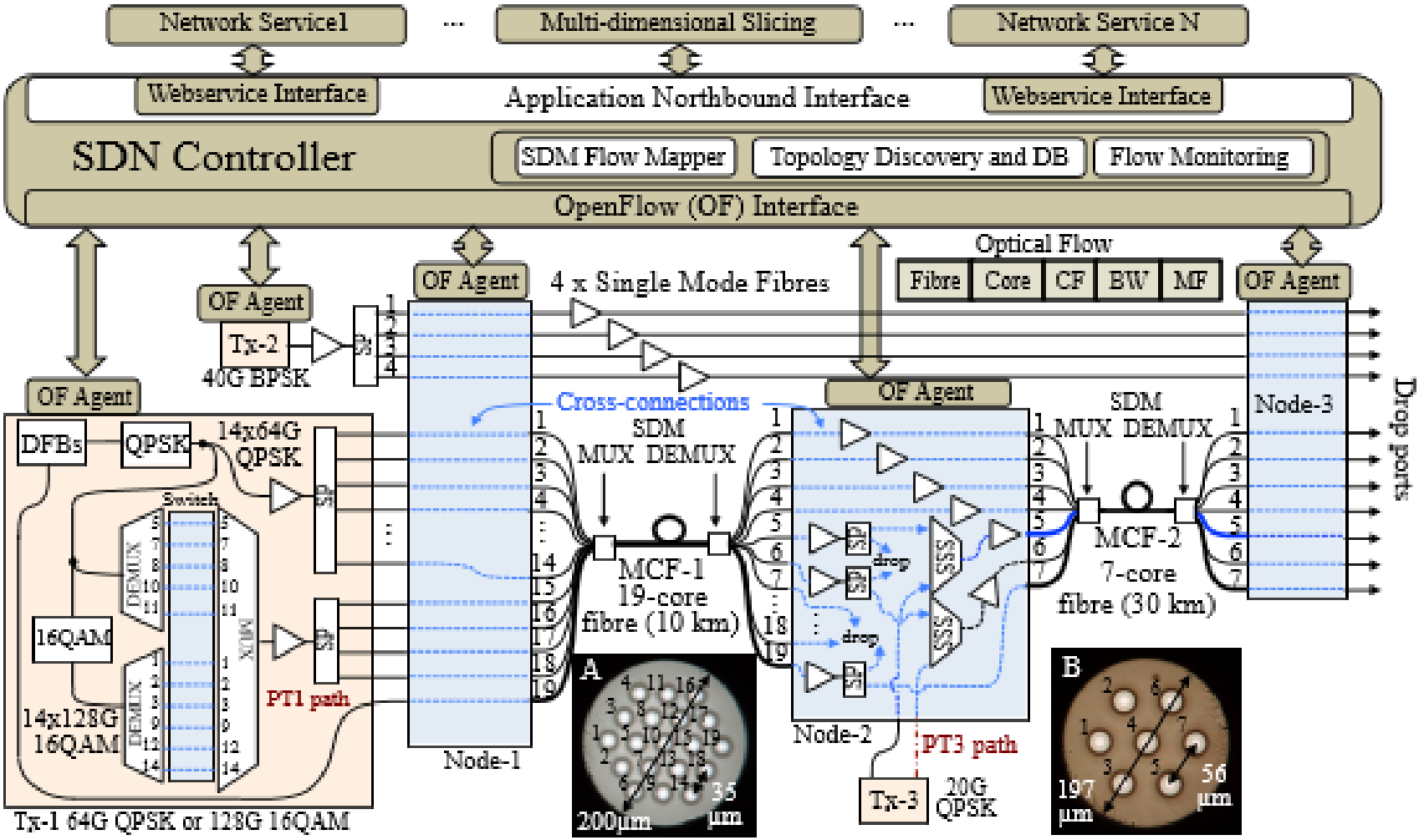


Fig. 1: Experimental setup of the SDN-controlled SDM network. Abbreviations: 16QAM: 16QAM emulator; BW: Bandwidth; CF: Centre Frequency; DFBs: DFB laser bank; MF: Modulation Format; QPSK: QPSK modulator; SP:splitter.

3. SDM and SDN features and benefits

This enables service level programmability of network.

- First demonstration of SDN-enabled control plane.

- Fully controlling the node architecture configuration and bandwidth provisioning, over an SDM network.

- Consists of three Architecture on Demand nodes

- The experimental setup is comprised of three programmable nodes and three transmitters

3. SDM and SDN features and benefits

- The SDM network enables efficient infrastructure utilization and high scalability.
- Hardware resources are efficiently used in the AoD nodes.
- As hardware modules are used only when and where required.
- It is also possible to split SDM network resources (e.g. using different cores or spectrum).

5. FDMA/TDMA/SDMA

- FDMA is the process of dividing one channel or bandwidth into multiple individual bands,
- Each for use by a single user.Each individual band or channel is wide enough to accommodate the signal spectra of the transmissions to be propagated.

- TDMA is a digital technique that divides a single channel or band into time slots.
- This technique works well with slow voice data signals, but it's also useful for compressed video and other high-speed data.

- SDM is the combination of FDM/TDM/CDM.
- SDM cannot use in isolation.

How to migrate towards SDM networking and deliver bandwidth at minimum cost?

i. Deliver SDM devices/system/functions across the network.

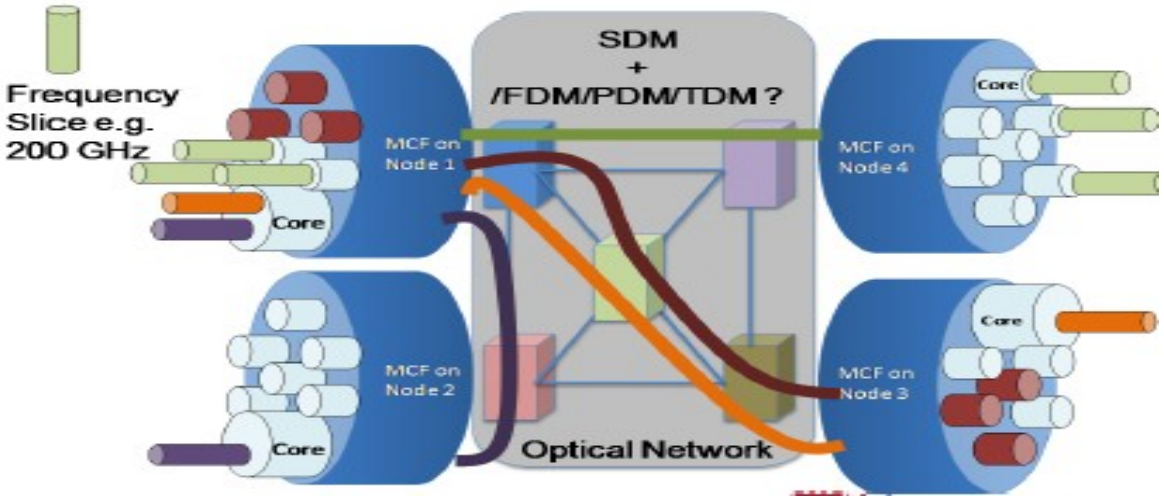
ii. Deliver SDM node that scale and are flexilble enough to support spatial dimension in addition to frequency.

i. Deliver a control/management system(e.g SDN).

ii. SDM particularities(e.g crosstalk,mode coupling etc).

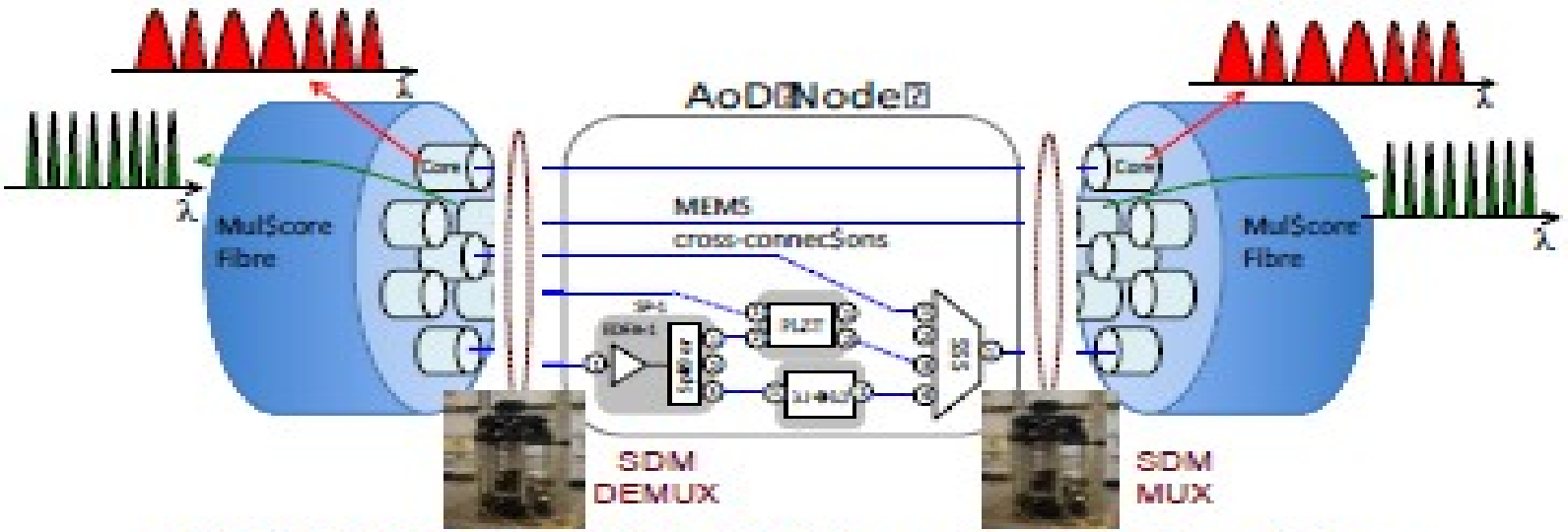
iii. Minimized complexity.

iv. Deliver at low cost.



Switching technologies for SDM networking

- Switching
  - At core level using MCF-SMF MUX/DEMUXes
  - At MCF level in conjuction with Frequency switching



SDM/FDM/TDM Switching and Networking Using MCF and Mux/Demuxes (Amaya, ECOC PDP 2012, OFC 2013)

6. SDM and WDM

i. Increasing bandwidth demands, caused by growing numbers of users.

ii. Increasing popularity of the Internet.

iii. Multi-media services, and higher demands on quality.

iv. The development of ever faster networks

v. To meet these Demands, optical techniques are being introduced in public.

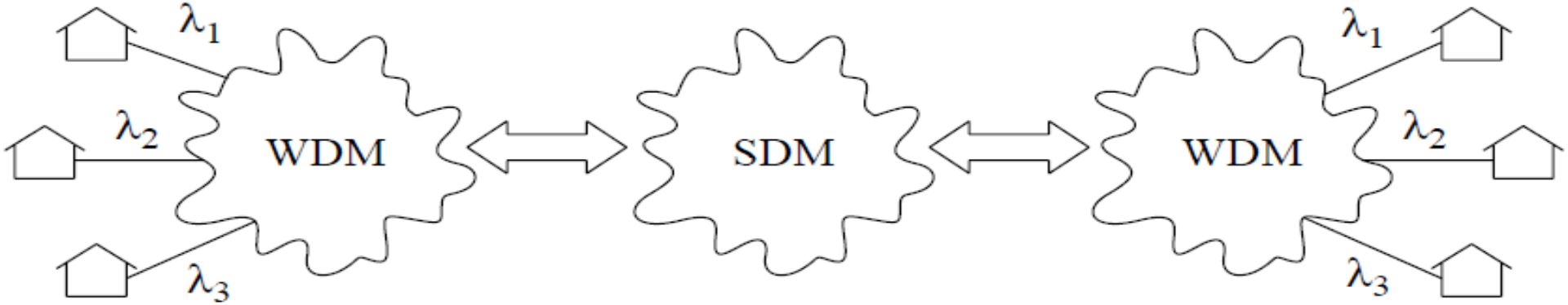
vi. Networks but on a link-to-link basis.

6. SDM and WDM

vii. A comparison is made of the strengths and weaknesses of two multiplexing techniques,Wavelength division multiplexing (WDM) and space division multiplexing.

xi. Both SDM and WDM are viable options for the optical layer of all-optical networks.

x. WDM enables networks with less fibres,less optical amplifiers, and less complex switches.



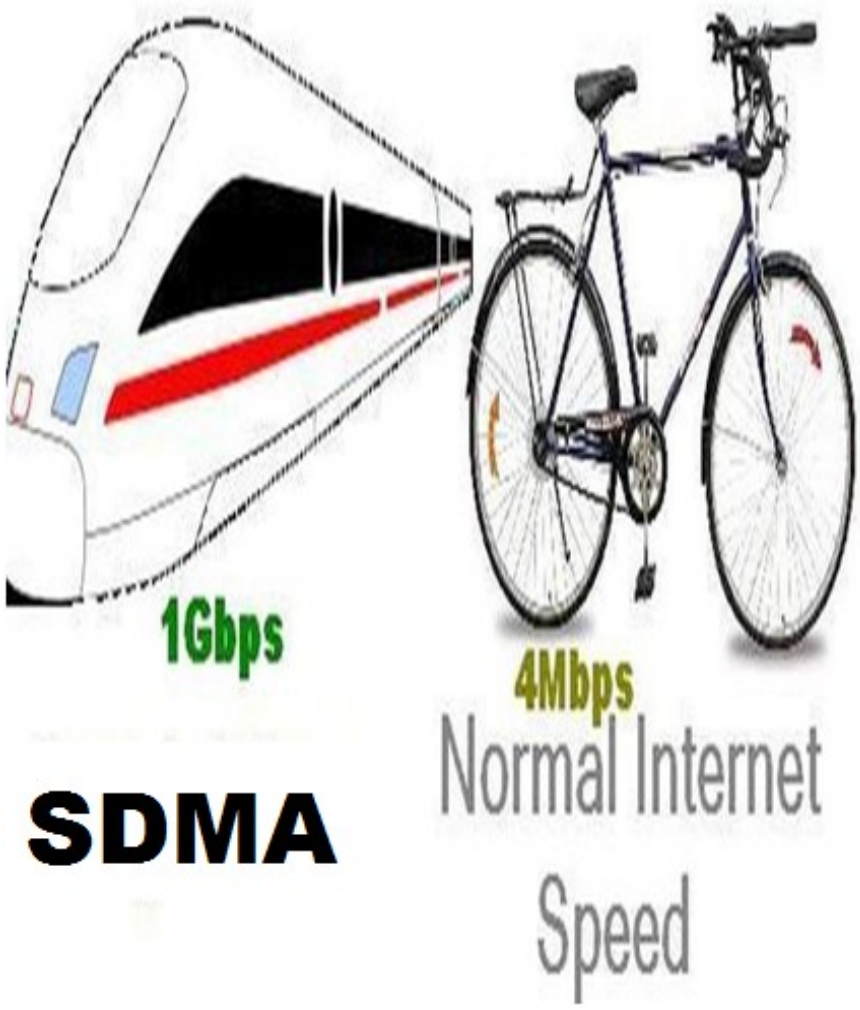
7. Advantage of SDM

- **Some of the advantages of SDMA are the fact that it can be a purely optical signal path.**
- **It is capable of terabit per second Tb/s throughput once the connection has been made.**
- **It is also transparent to the system if its purely optical.**
- **You can use any bandwidth or data rate achievable in fiber**
- The main advantage of SDMA is frequency reuse.

- Provided the reuse distance is preserved in the network

7. Advantage of SDM

- Two different signals then can use the same frequency.
- One transmitting a vertically polarized signal and the other transmitting a horizontally polarized signal.
- It isusually combined with other multiplexing techniques to better utilize the individual physical channels.

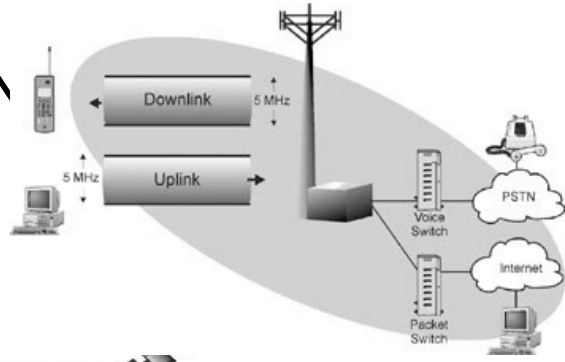


8. Disadvantage of SDM

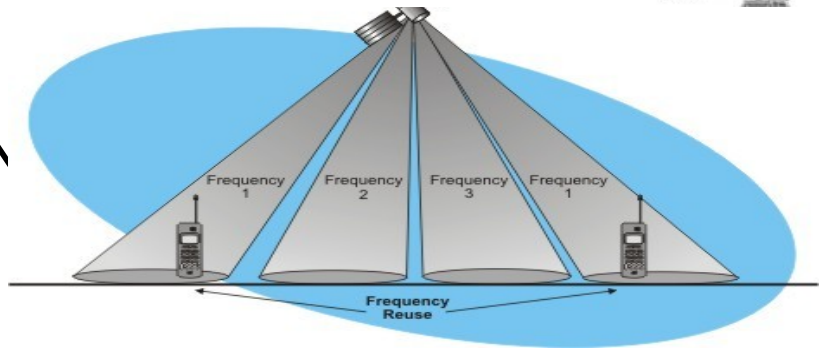
- In FDM there is need of filters, which are very expensive and complicated to construct and design
- Some of the disadvantages of SDMA is the fact that the number of switches.
- There are also high insertion losses since each input must have the capability to be split to any output.
- It is also not easy to add additional inputs and outputs, the whole switch must be replaced.
- Reverse link may be a problem: interference problems

Where SDMA is used:

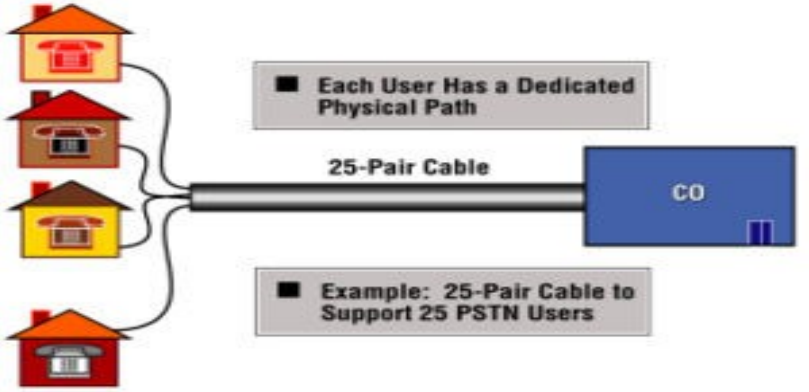
- In WIRELESS/MOBILE COMMUNICATION



- In SATELLITE COMMUNICATION



- In OPTICAL COMMUNICATION.



9. Uses of SDM?

- SDMA a channel access method used in communication.
- As fiber comes closer to the home, the need for switching between purely optical paths becomes more important.
- SDMA is the way to achieve this.
- SDMA is a fairly mature technology and therefore available today.
- Switching is done nowadays with **optoelectronic switches.** SDMA can also be used in conjunction with WDM and TDM.

9. Uses of SDM?

- **SDMA technology is used to complement WDM and TDM**
  and is not something to take their place.

- **When a WDM or TDM signal is sent into a SDMA switch**
  matrix, the same signal will come out.

- Different areas may be served by same frequency: TDMA or CDMA, or different frequencies: FDMA

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Thank
You