Overview

- This Lecture
  - LiFi
  - Network on Chips
  - Quantum network

Overview

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  - LiFi
    - Introduction of LiFi
    - Potential Applications
    - Challenging Problems
  - Network on Chips
  - Quantum network

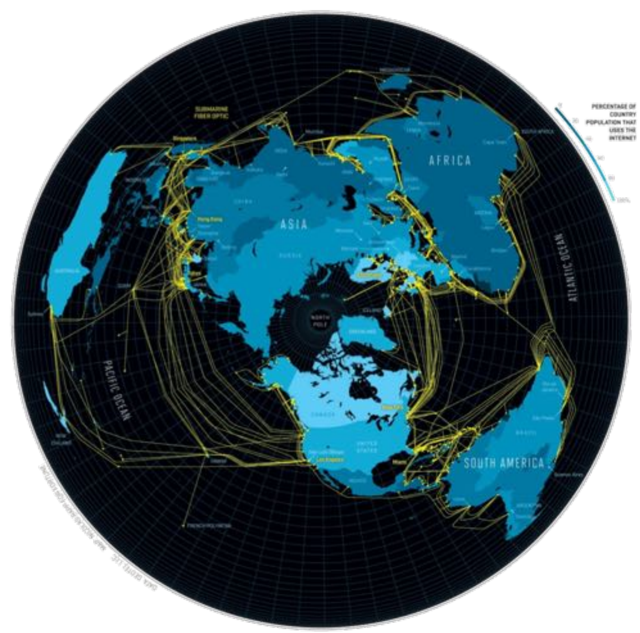
Introduction of LiFi

- Optical Wireless Communication(OWC)

Optical Communications:

The Backbone of Telecommunications

Optical fibers around the world



Introduction of LiFi

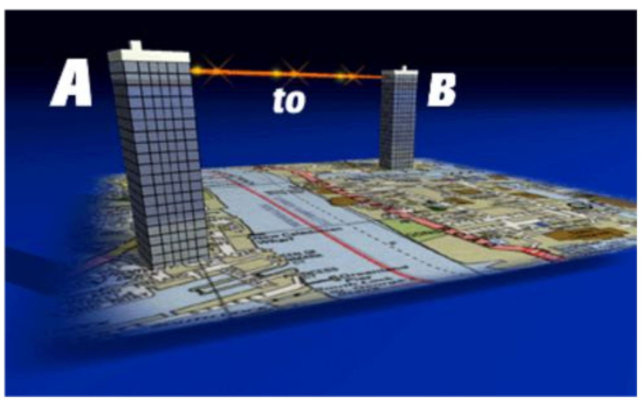
- Optical Wireless Communication(OWC)

Wireless Communications:

The most common wireless technologies use radio waves (Wifi, Cellular network)

Introduction of LiFi

- Optical Wireless Communication(OWC)
  - a form of optical communication in which unguided visible, infrared (IR), or ultraviolet (UV) light is used to carry a signal



Introduction of LiFi

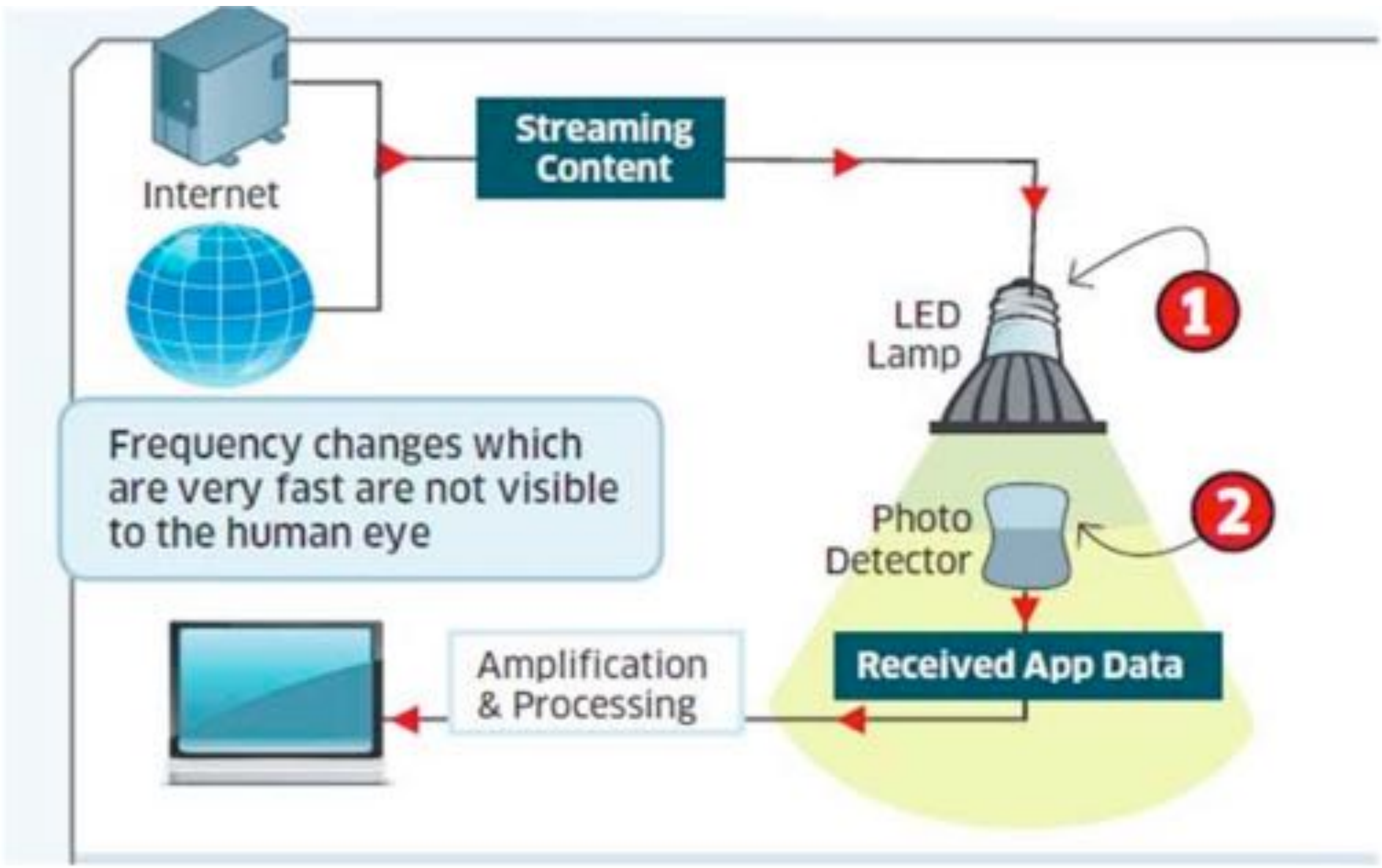
- Visible light communications (VLC)
  - Li-Fi ----Light Fidelity, Prof. Harald Haas during his TED Global talk, 2011 (https://www.youtube.com/watch?v=ujO3hq0_tJ0)
  - a light-based Wi-Fi, uses LED light instead of radio waves to transmit information.

Introduction of LiFi

- Switching bulbs on and off within nanoseconds
- Switching on is a logic al ‘1’, switching it off is a logical ‘0’, so fast that human eye doesn’t notice (thousands of times per second)
- A demo of “Wi-fi makes room for Li-fi”
  (https://www.youtube.com/watch?v=trYBogpHHGY)

Introduction of LiFi

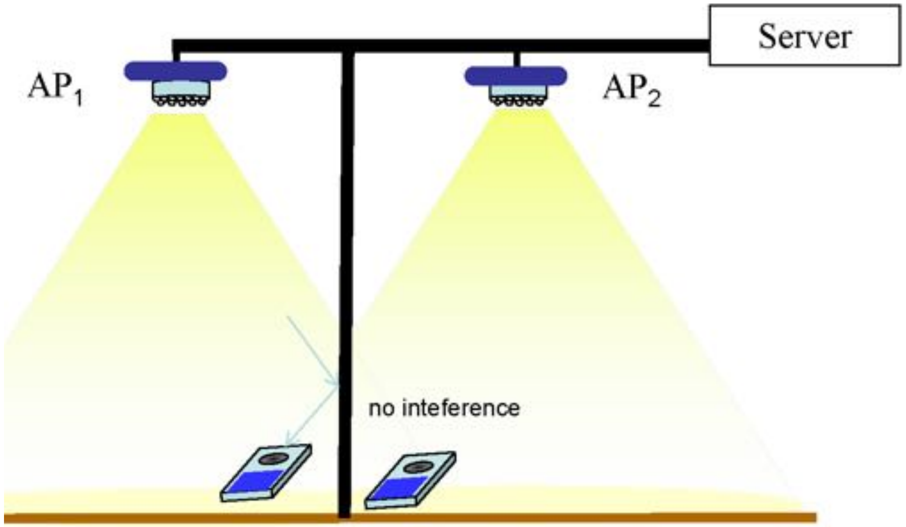
- Li-Fi uses LED lamps that can light a room as well as transmit and receive information.
(https://www.youtube.com/watch?v=AKvvEqm9Nv4)



http://phys.org/news/2012-10-li-fi-edinburgh-prof-seeds.html

Introduction of LiFi

- Advantages
  - Safe for health
  - Secure
  - No interference on radio wave signals
  - High speed



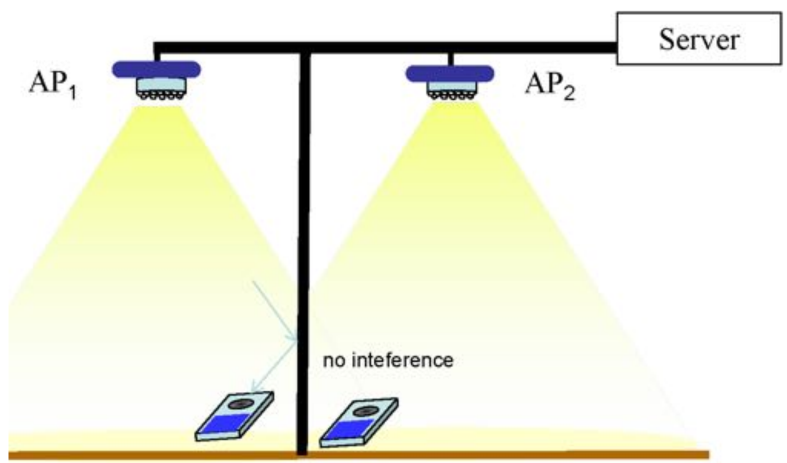
(>10 Gbps, meaning one can download a full high-definition film in just 30 seconds)

Why is Li-Fi so much faster?

Visible light is far more dense than radio waves,
10,000 times more dense
in fact, meaning much more data can be transferred

Introduction of LiFi

- Disadvantages
  - Li-Fi doesn't work in the dark
  - cannot move to other rooms unless there are wired bulbs too
  - low-mobility
  - small-coverage



Introduction of LiFi

	Li-Fi	Wi-Fi
Operation	Use LED	Use modem
Data Transfer Speed	>1 Gbps	About 150 Mbps
Security	High	Low
Cost	Lower, visible light spectrum is free	Higher, radio spectrum requires license
Power Consumption	Less	More

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Potential Applications

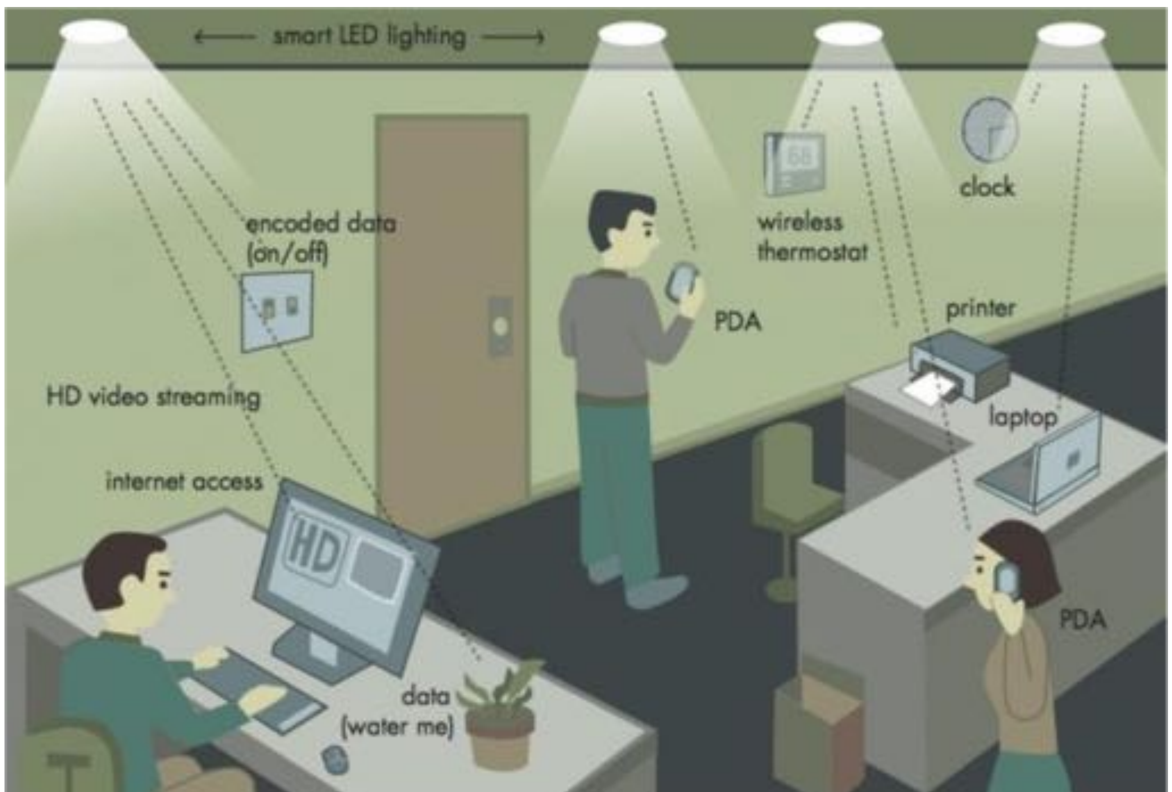
- LiFi can provide network access at home, office, shopping center, plane, hospital, convention centers
- A demo of VLC wireless LAN system (https://www.youtube.com/watch?v=GH-xnS8yG8M)





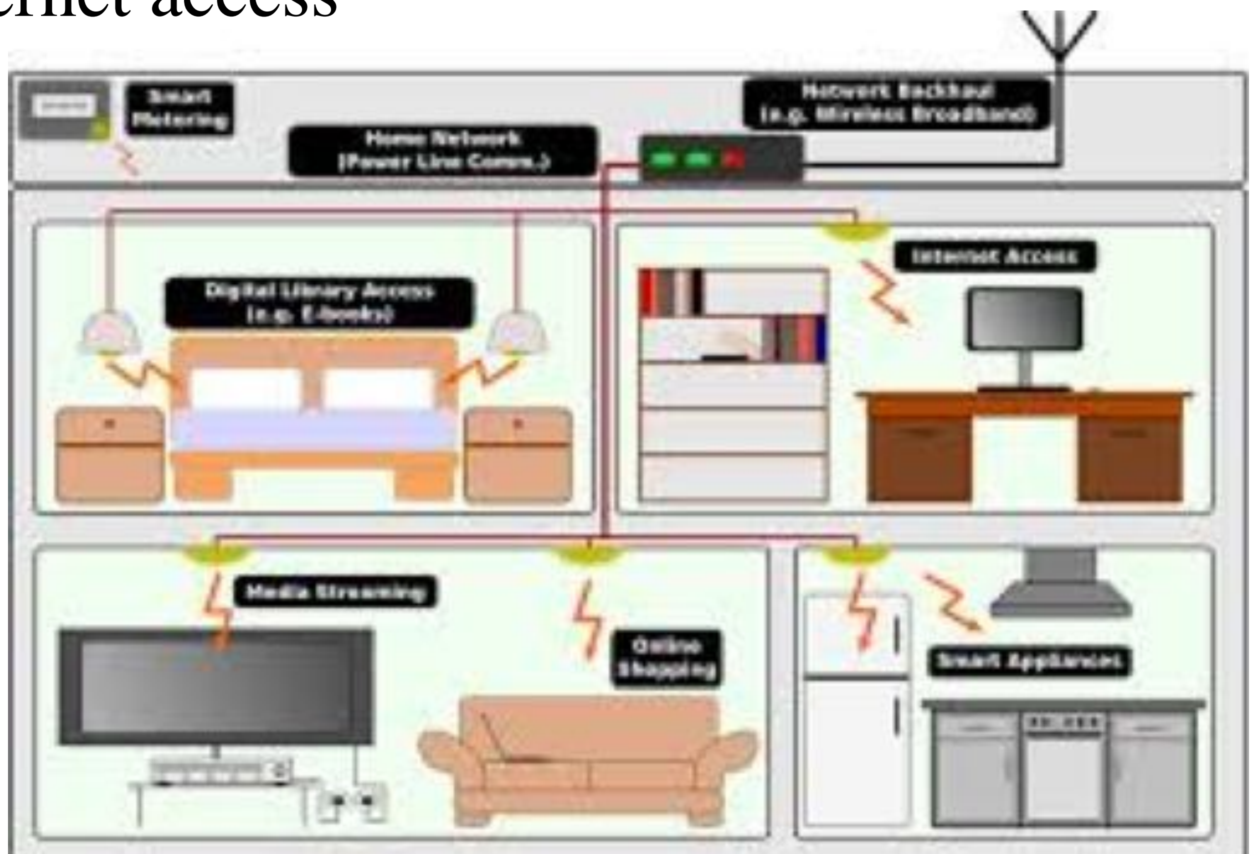
Potential Applications

- **WiFi Spectrum Relief** - Providing additional bandwidth in environments where licensed and/or unlicensed communication bands are congested (complementary to WiFi)



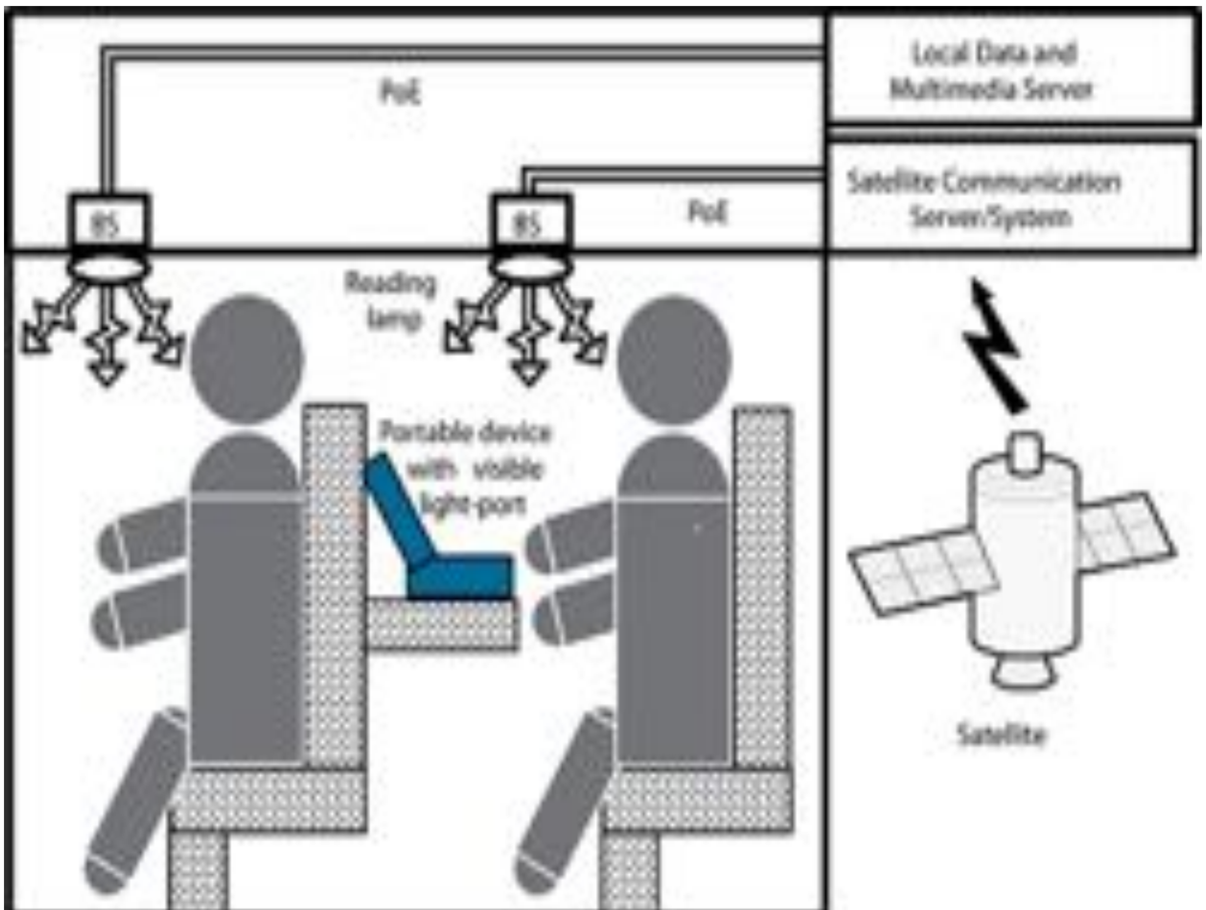
Potential Applications

- **Smart Home Network** – Enabling smart domestic/industrial lighting; home wireless communication including media streaming and internet access



Potential Applications

- **Commercial Aviation** – Enabling wireless data communications such as in-flight entertainment and personal communications

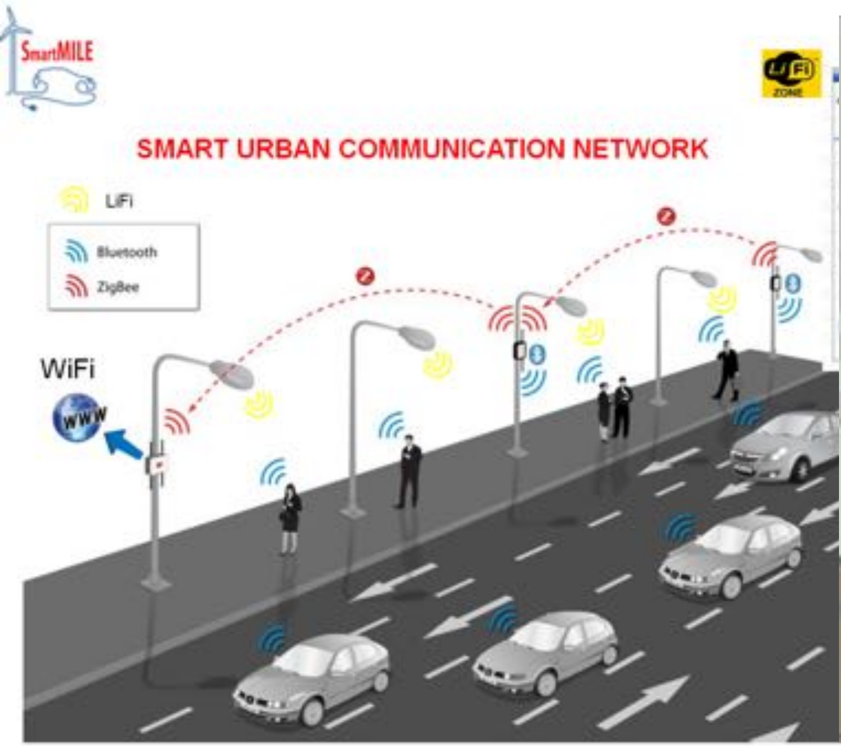


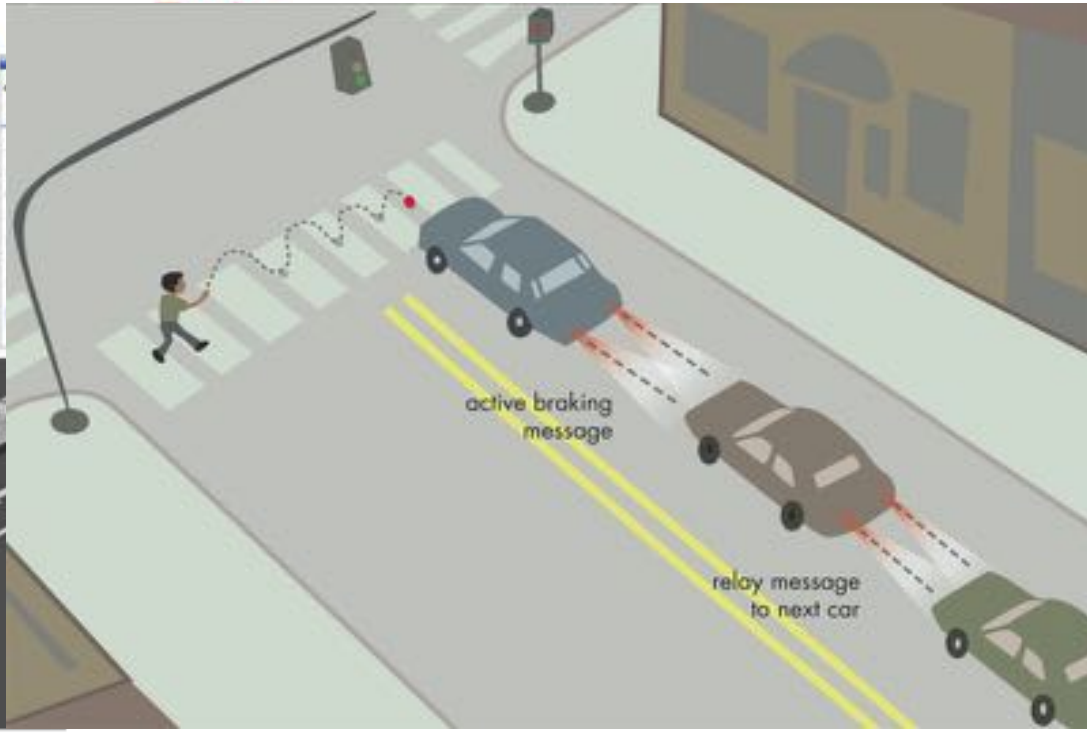
Potential Applications

- **Hazardous Environments**- Enabling data communications in environments where RF is not available, such as oil & gas, petrochemicals and mining

Potential Applications

- **Vehicles & Transportation:** Street lamps, signage and traffic signals are also moving to LED. This can be used for vehicle-to-vehicle and vehicle-to-roadside communications. This can be applied for road safety and traffic management.



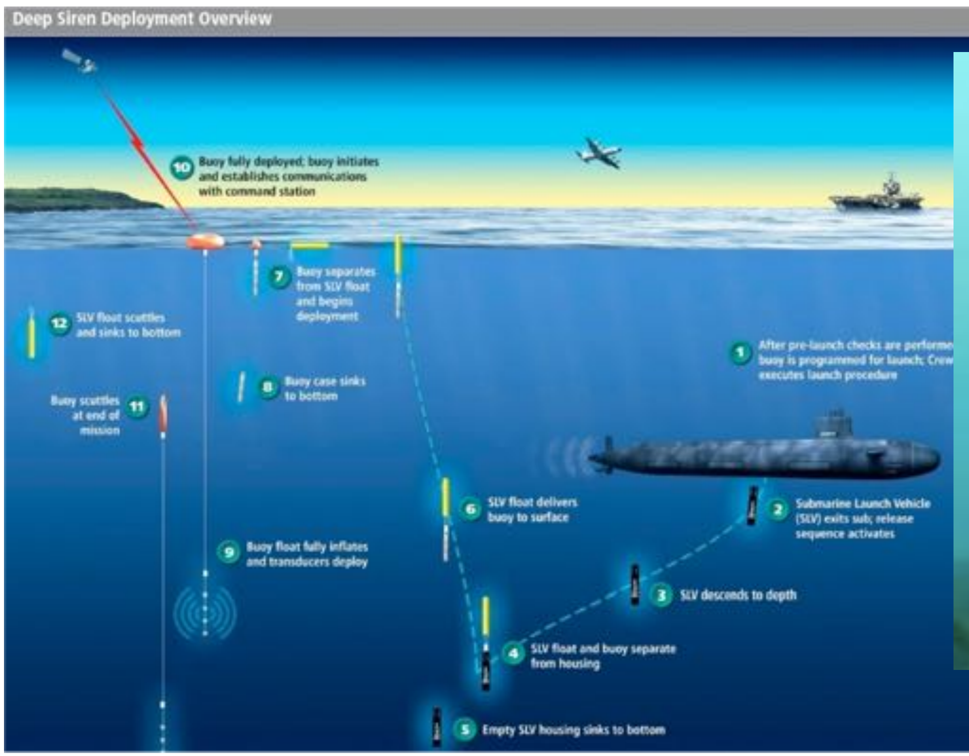


Potential Applications

- **Hospital and Healthcare** – Li-Fi emits no electromagnetic interference and so does not interfere with medical instruments, nor is it interfered with by MRI scanners.

Potential Applications

- **Underwater Communications**: Due to strong signal absorption in water, RF use is impractical. Li-Fi provides a solution for short-range communications.



Potential Applications

- **Defence and Military Applications** – Enabling high data rate wireless communication within military vehicles and aircraft
- **Corporate and Organisational Security** – Enabling the use of wireless networks in applications where (WiFi) presents a security risk
- **Location-Based Services** – Highly accurate location-specific information services such as advertising and navigation that enables the recipient to receive appropriate, pertinent information in a timely manner.
- **Toys** – Many toys incorporate LED lights and these can be used to enable extremely low-cost communication between interactive toys

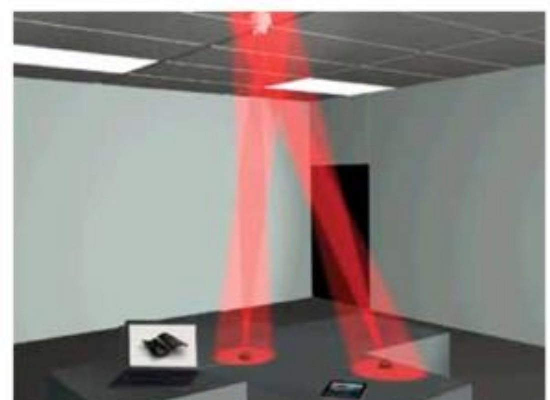
Models

- Li-Fi Consortium defined Giga Dock, Giga Beam, Giga Shower, Giga Spot and Giga MIMO models to tackle different user scenarios.

(a) GigaDock

(b) GigaBeam

(c) GigaShower



(d) GigaMIMO

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Challenging Problems

- Challenging Problems
  - Shadowing (easily blocked by somebody simply walking in front of LED source)

Challenging Problems

- Challenging Problems

Interferences from external light sources like sun light, normal bulbs, and opaque materials in the path of transmission will cause interruption in the communication.

A major challenge facing Li-Fi is how the receiving device will transmit back to transmitter.

Challenging Problems

- Challenging Problems

VLC can be used for transmission in either direction, however downlink-only implementations are simpler

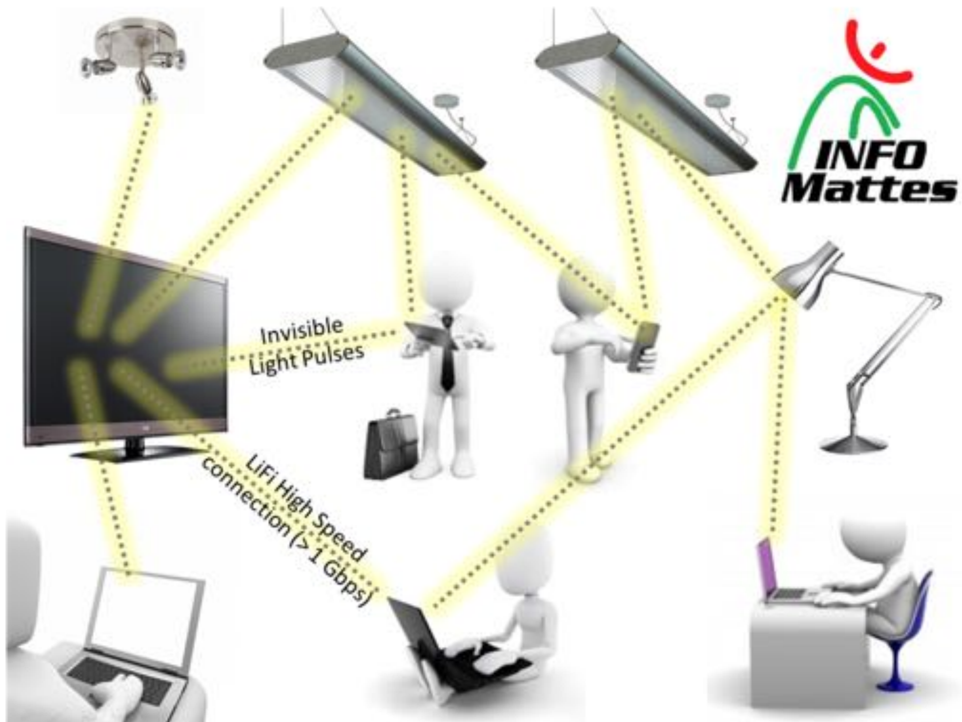
Challenging Problems

- Challenging Problems
  - LED layout problem (Lifi requires line of sight, limited coverage, different indoor/outdoor conditions)

The possibilities are numerous and can be explored further. If this technology can be put into practical use , every bulb can be used something like a Wi-Fi hotspots to transmit wireless data.

Challenging Problems

- Challenging Problems
  - ➢ Connectivity while moving (transferred from one light source to another, seamless handover)
  - ➢ Multiuser support (multiplexing)



Summary of LiFi

- IEEE 802.15.7 visible light communication
- VLC technology has been proven to work by a number of companies (Lifi Consortium, Purevlc..,) and research establishments. (See Demos of Pure LiFi at Mobile World Congress 2014/2015)
- Amazing Fact about Li-Fi
  - Every light source in homes and offices could potentially be a "Li-Fi" within 20 years.
  - When this technology becomes feasible like the WiFi, then our life will be awesome on earth.
  - "This is the technology that could start to touch every aspect of human life within a decade"

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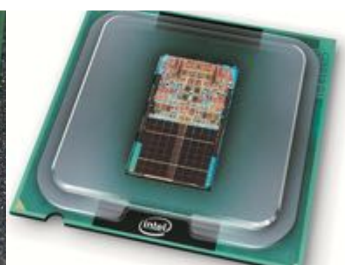
    - Introduction of OWC
    - Potential Applications
    - Challenging Problems
  - Network on Chips
    - Introduction of NoC
    - Types of NoC
    - Challenging Problems

Introduction of NoC

- **many cores on a single chip** (e.g. processors, GPUs), such as, Cisco QuantumFlow (40), Intel Teraflops (80), Tilera Tile (100), Cisco SPP (188), CSX700 (192), PicoChip (300), etc.
- It has been predicted **more than 1000 cores** will be integrated on a single chip.

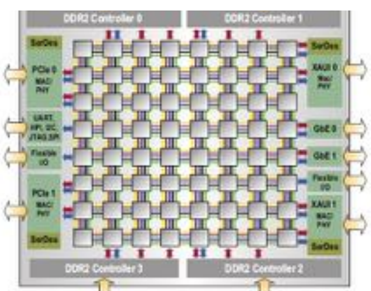
Multicore processor with more and more cores!!

2005, Pentium D

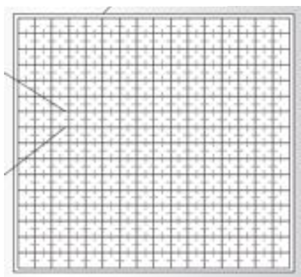


2006, Core 2 Duo
(Conroe)

2006, Core 2 Quad
(Kentisfield)

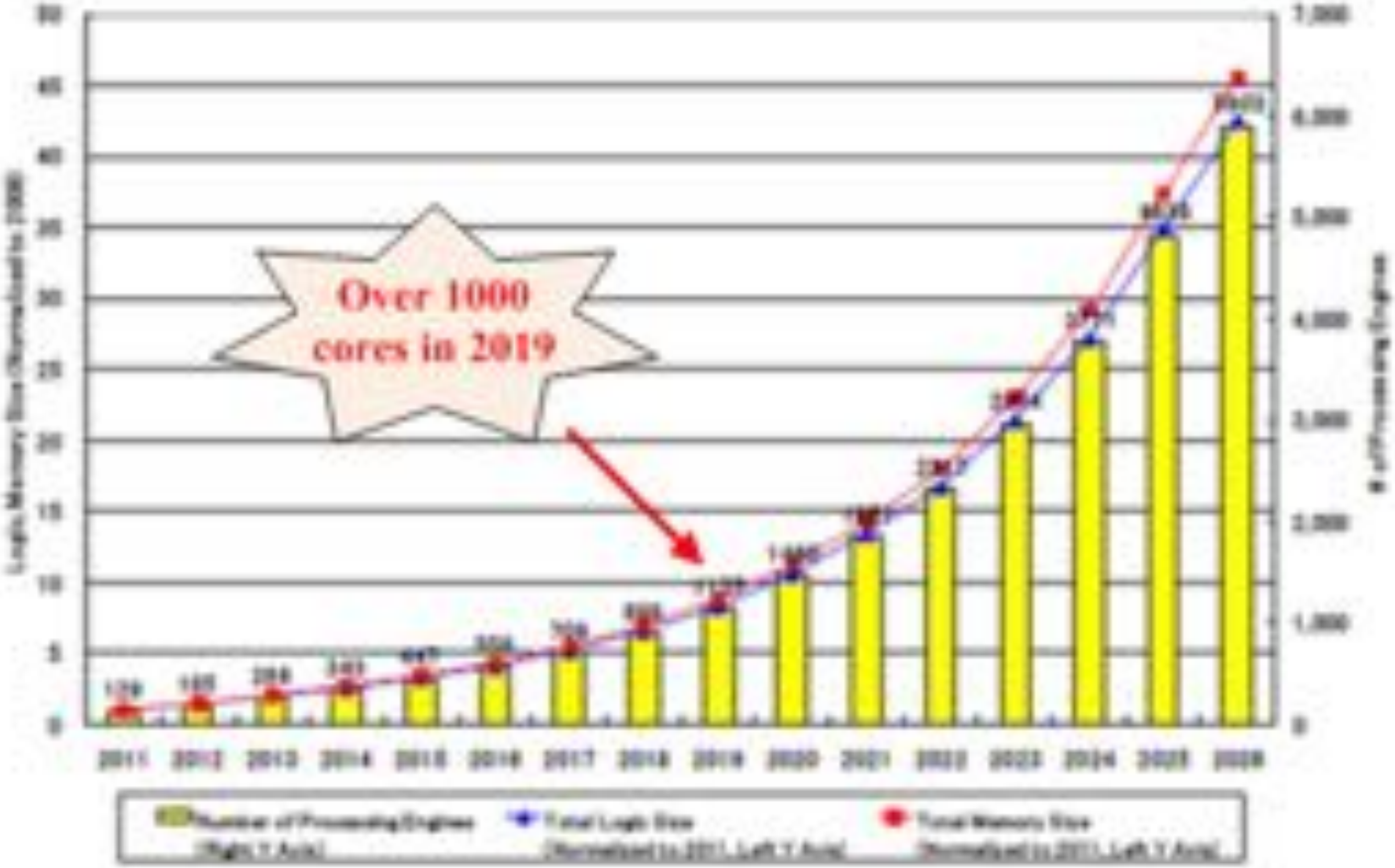


2007, TILE64
(Tilera)



2015. 256 cores
Intel, Sun

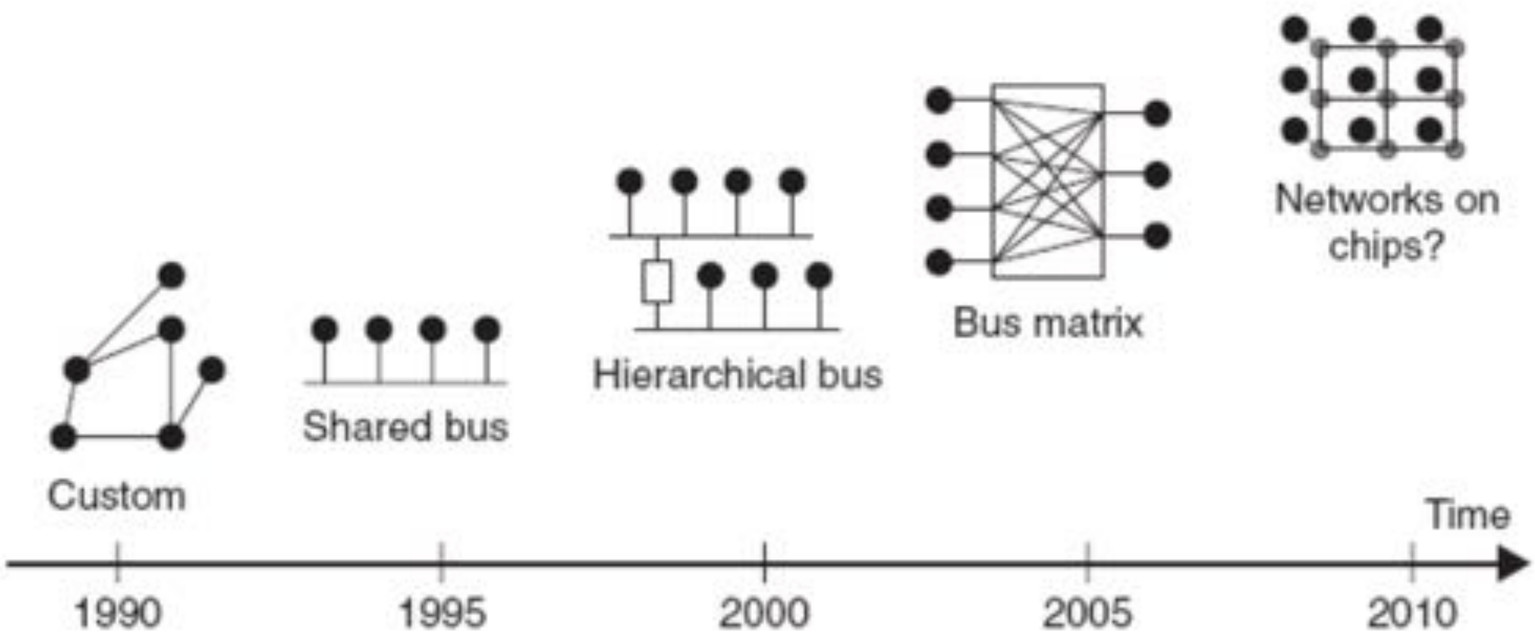
Introduction of NoC



International Technology Roadmap for Semiconductors (ITRS) Predictions in 2010

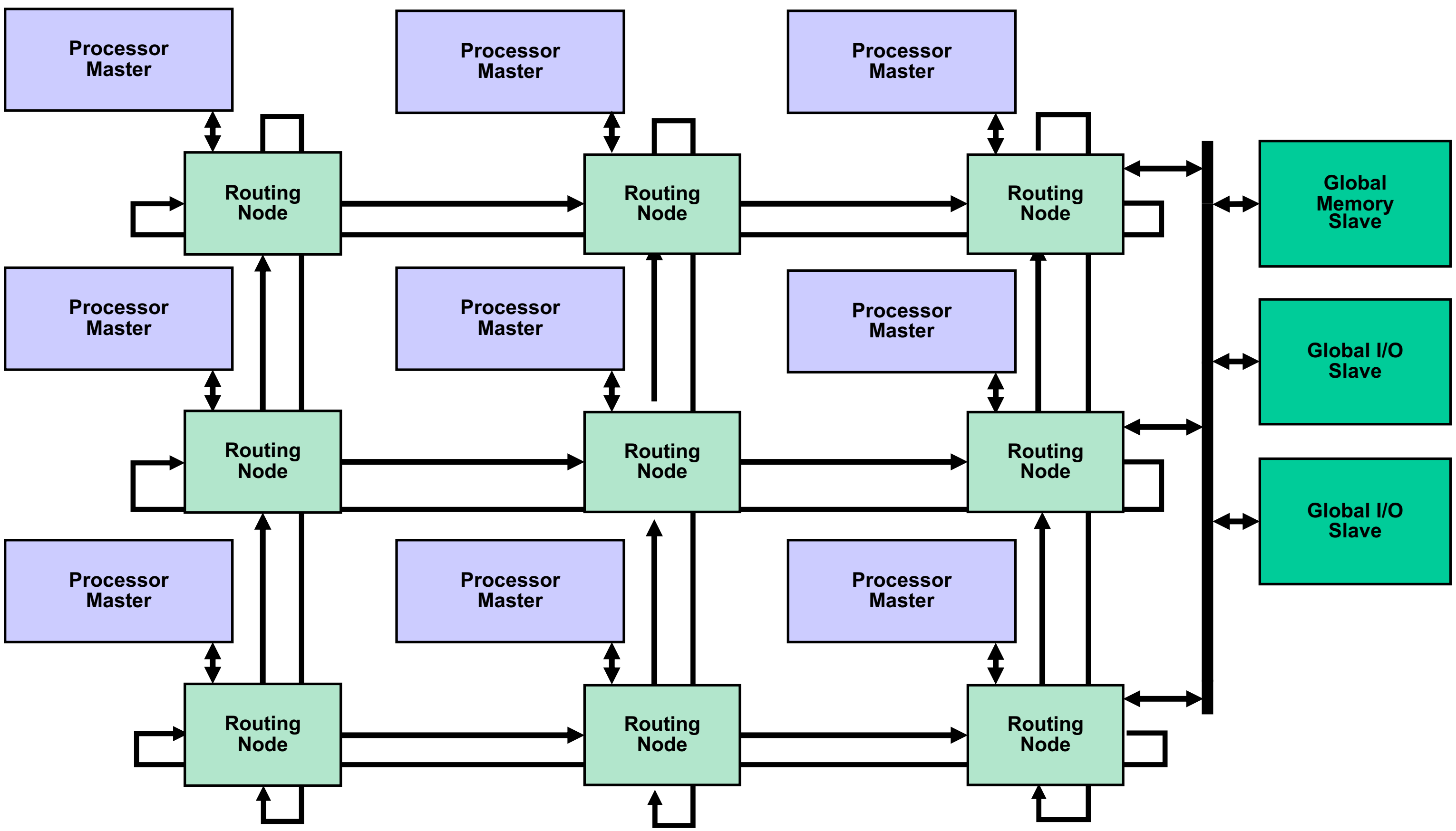
Introduction of NoC

- Evolution of on-chip communication architectures



Introduction of NoC

- NoC exemple



Introduction of NoC

- NoCs: scale down the concepts of large scale networks, and apply them to the embedded system-on-chip (SoC) domain (demo example)
- NoC Properties
  - Regular geometry that is scalable
  - Flexible QoS guarantees
  - Higher bandwidth
  - No long global wires
  - Reliable electrical and physical properties

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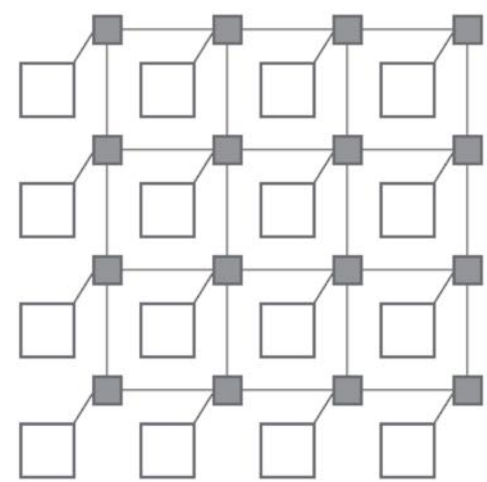
  - Network on Chips
    - Introduction of NoC
    - Design of NoC
    - Challenging Problems

Types of NoC

- Networks with new constraints
  - Need to accommodate interconnects in a 2D layout
  - Cannot route long wires
  - area and power
  - Use as few buffers as possible

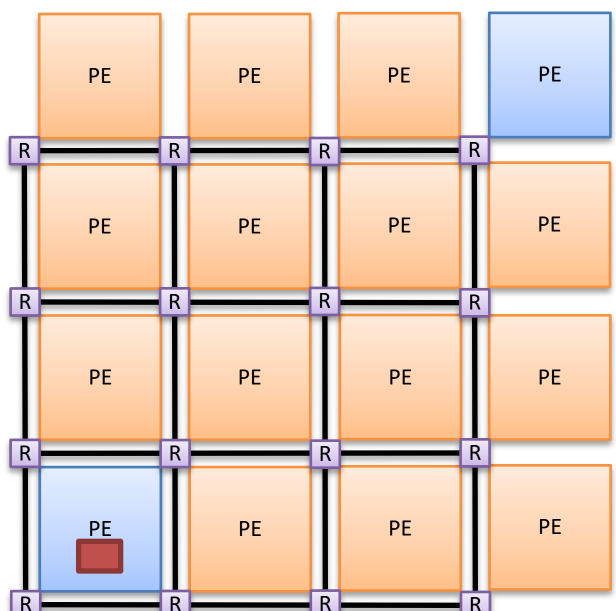


NoC Topology

- Mainly adopted from large-scale networks and parallel computing
- A good topology allows to fulfill the requirements of the traffic at reasonable costs
- Topology classifications:
  1. Direct topologies
  2. Indirect topologies

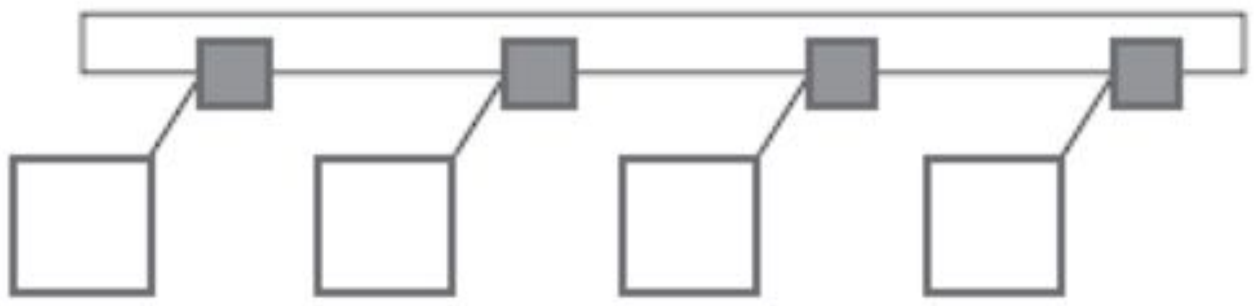
Types of NoC

- 2D mesh is most popular topology
  - all links have the same length
  - area grows linearly with the number of nodes
  - must be designed in such a way as to avoid traffic accumulating in the center of the mesh



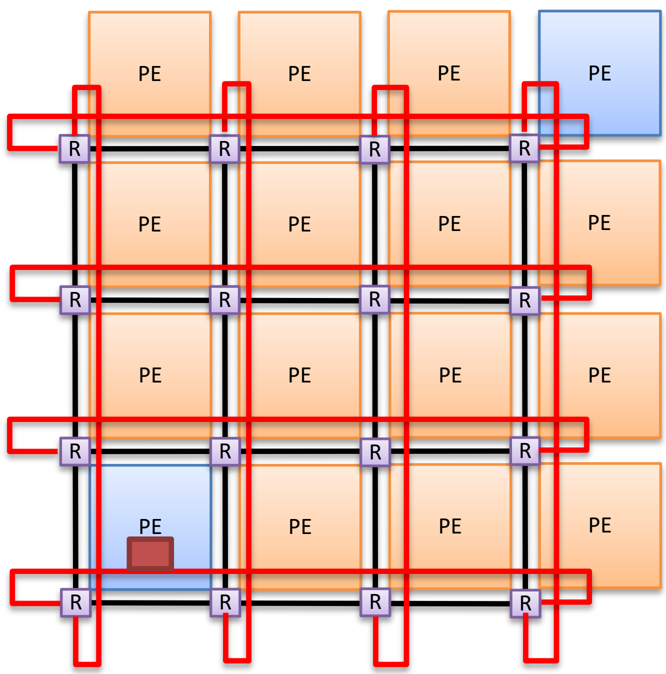
Types of NoC

- Torus topology, also called a k-ary n-cube, is an n-dimensional grid with k nodes in each dimension
  - k-ary 1-cube (1-D torus) is essentially a ring network with k nodes



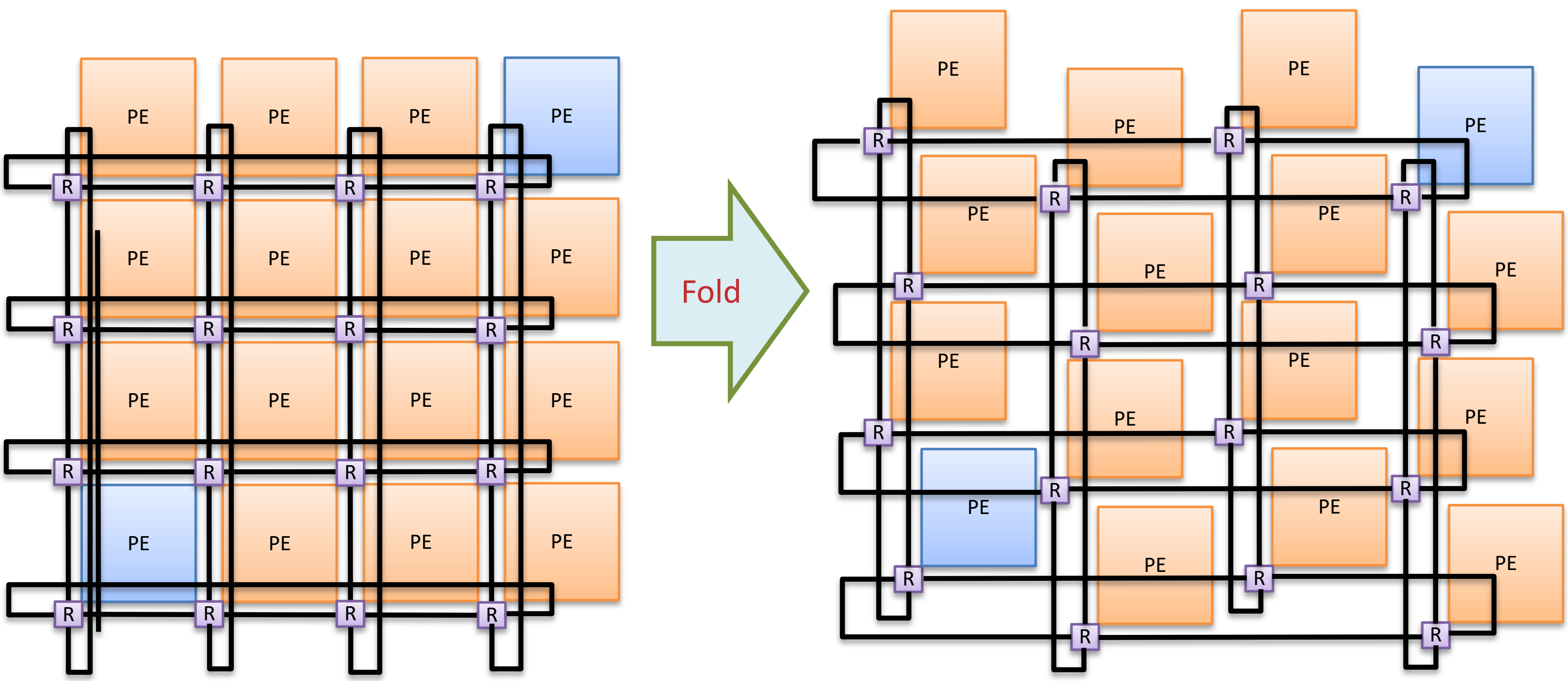
Types of NoC

- k-ary 2-cube (i.e., 2-D torus) topology is similar to a regular mesh except that nodes at the edges are connected to switches at the opposite edge via wrap-around channels



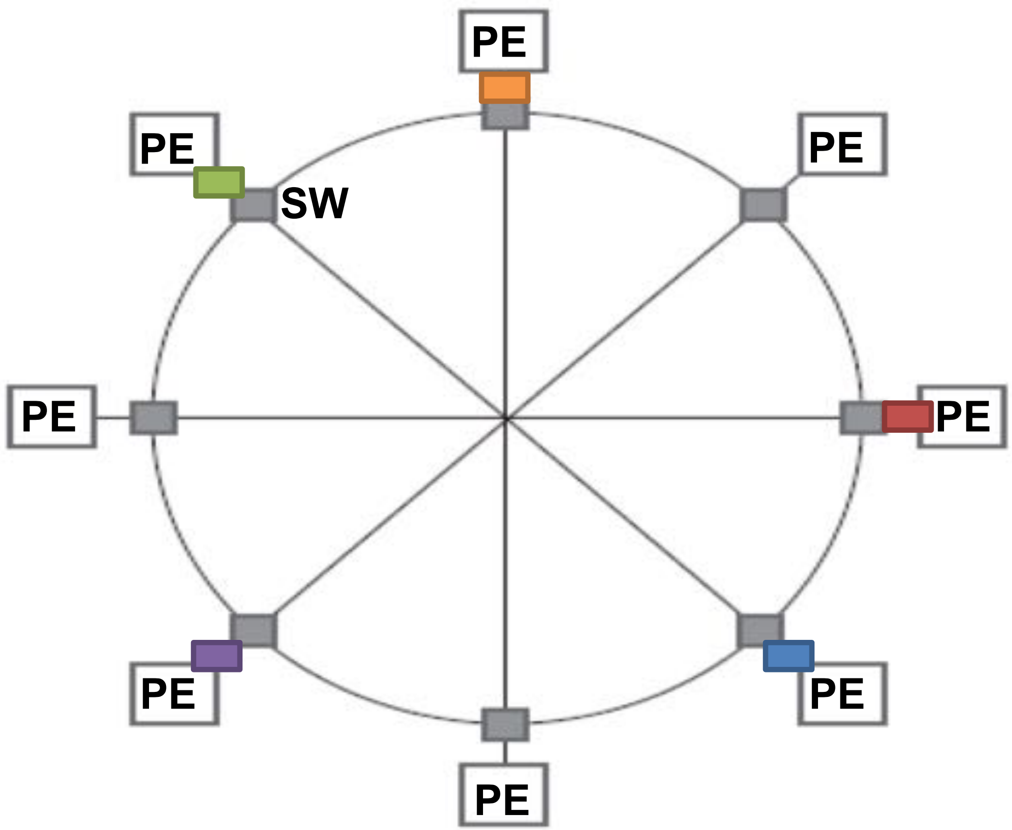
Types of NoC

- Folding torus topology overcomes the long link limitation of a 2-D torus
  - links have the same size



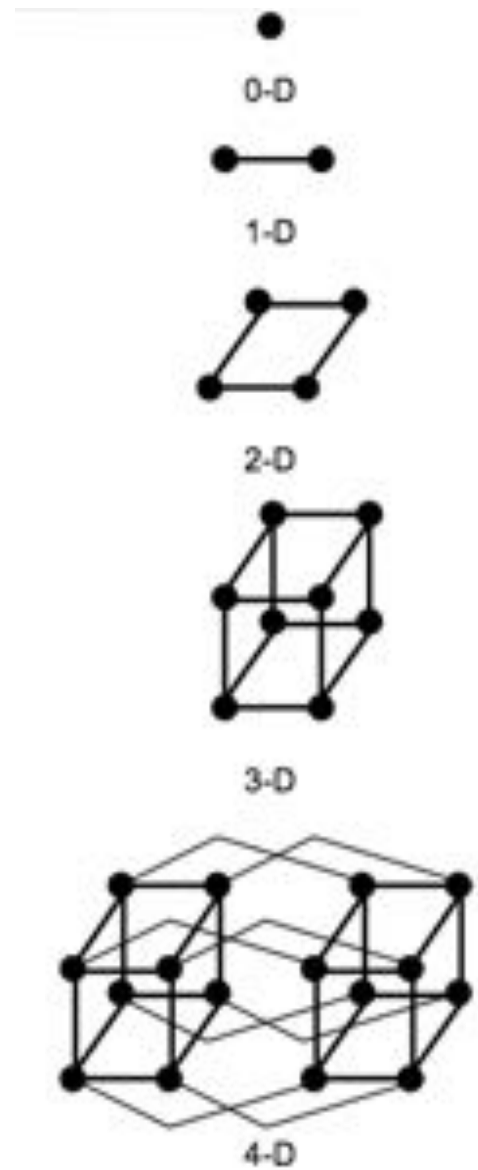
Types of NoC

- Octagon topology : messages being sent between any 2 nodes require at most two hops



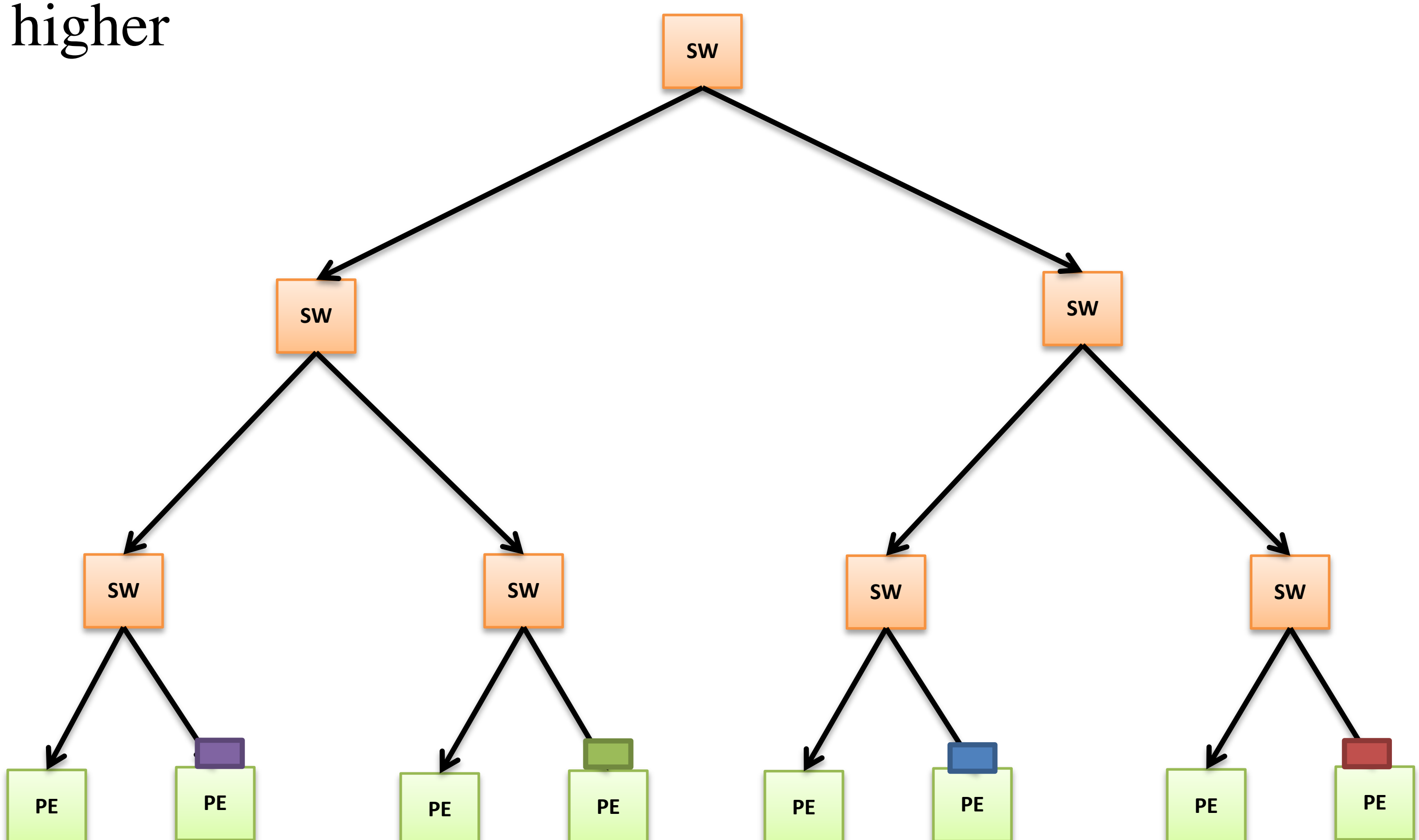
Types of NoC

- hypercube topology : Arrange $N=2^n$ nodes in n-dimensional cube
  - At most n hops from source to destination
  - log(number of nodes)



Types of NoC

- Fat tree topology (Indirect)
  - nodes are connected only to the leaves of the tree
  - more links near root, where bandwidth requirements are higher



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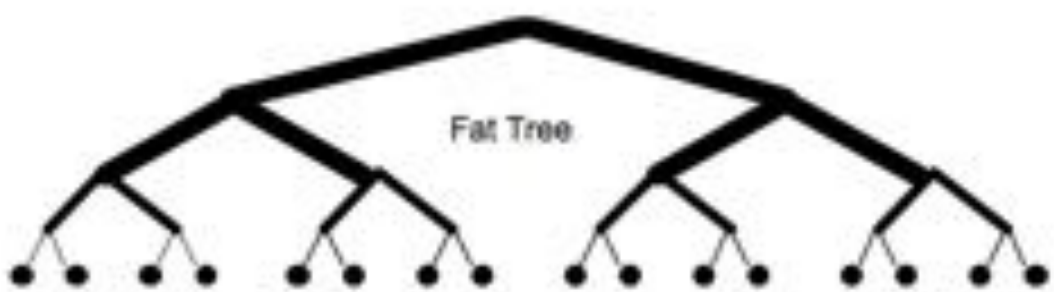
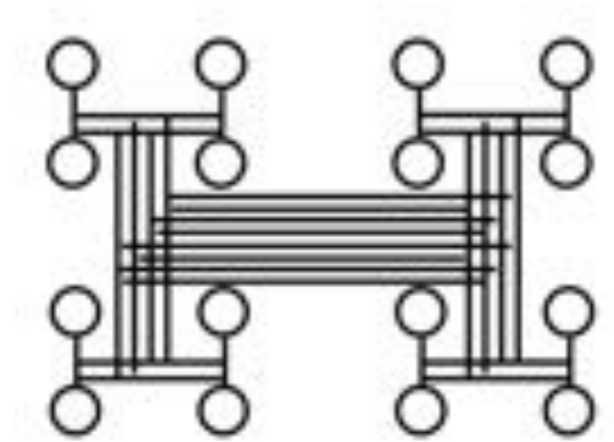
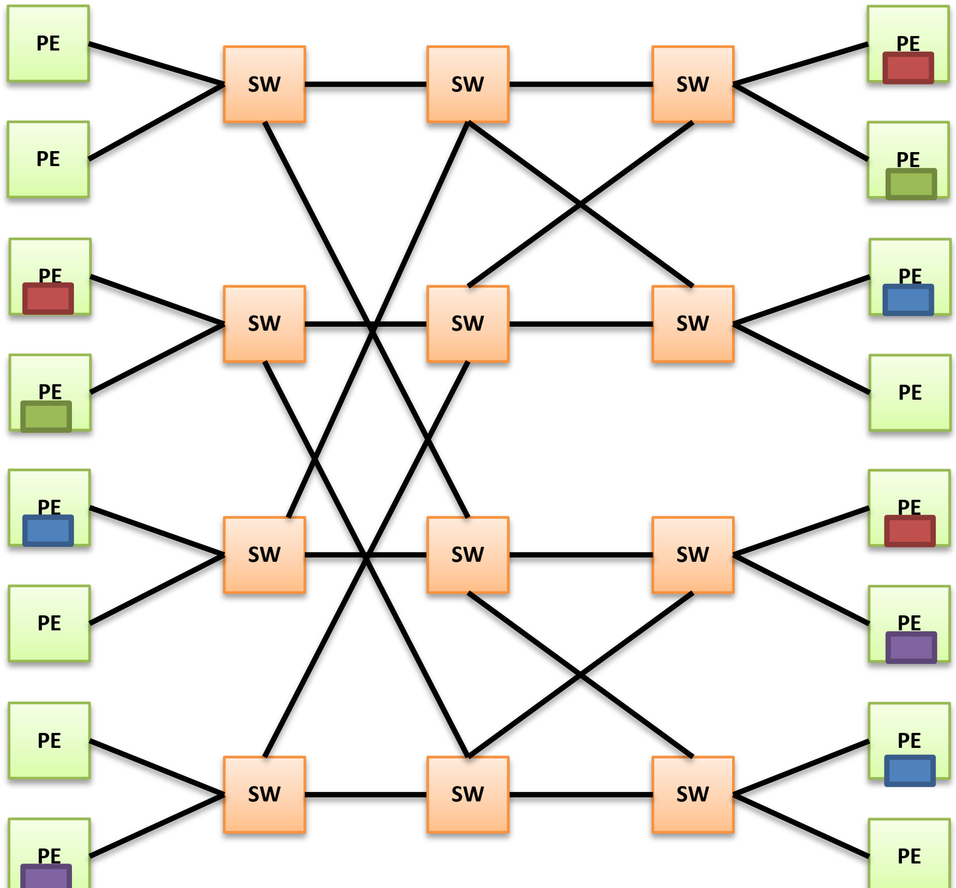




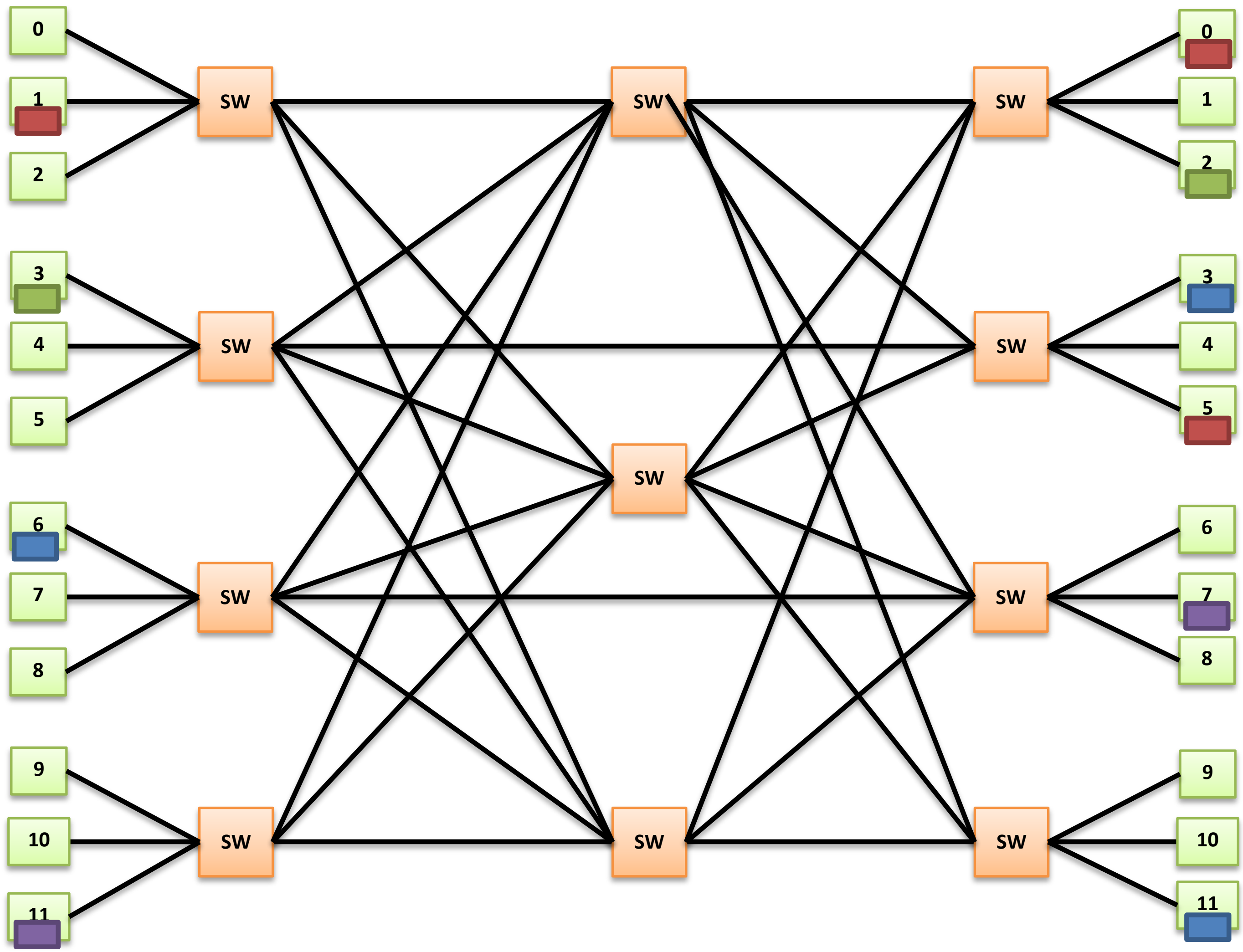
Types of NoC

- k-ary n-fly butterfly network
  - multi-stage network; k^n nodes, and n stages of k^{n-1} k x k crossbar. e.g. 2-ary 3-fly butterfly



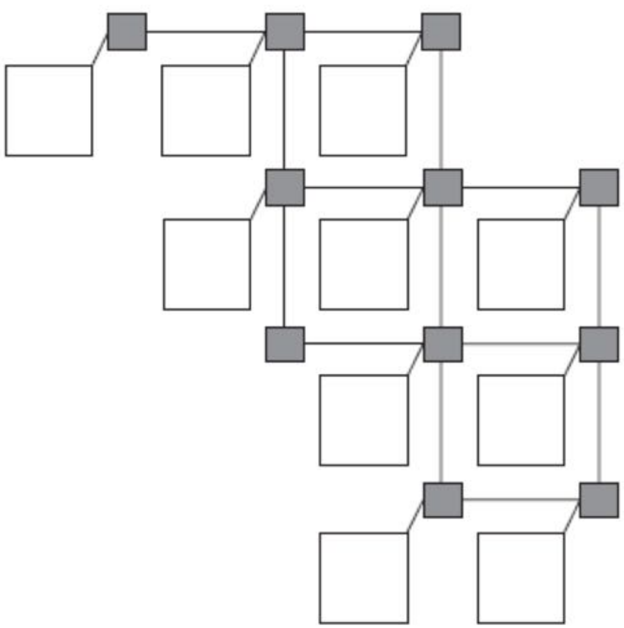
Types of NoC

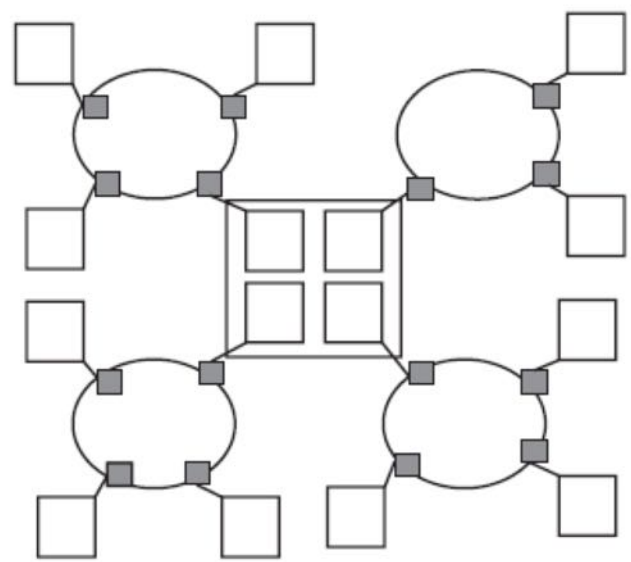
- (m, n, r) symmetric Clos network: m is the no. of middle-stage switches; n is the number of input/output nodes on each input/output switch; r is the number of input and output switches; e.g. (3, 3, 4) Clos network



Types of NoC

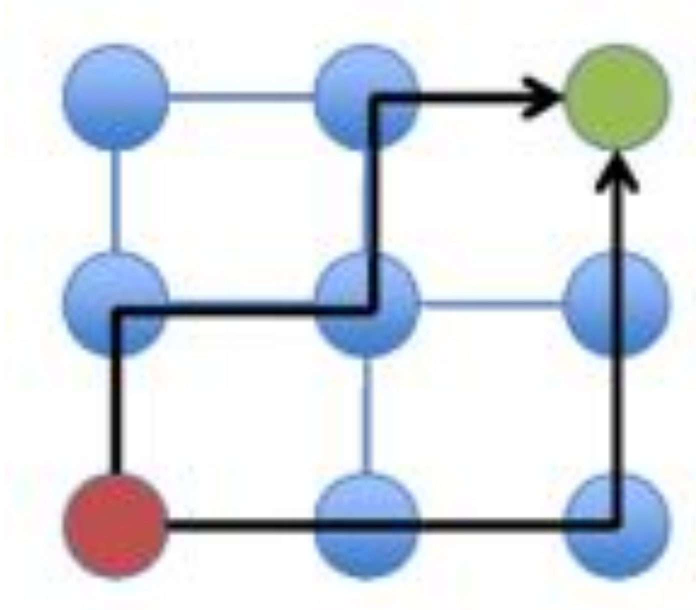
- Irregular or ad hoc network topologies
  - customized for an application
  - usually a mix of shared bus, direct, and indirect network topologies
  - e.g. reduced mesh, cluster-based hybrid topology





NoC Routing

Routing algorithm determine path(s) from source to destination.

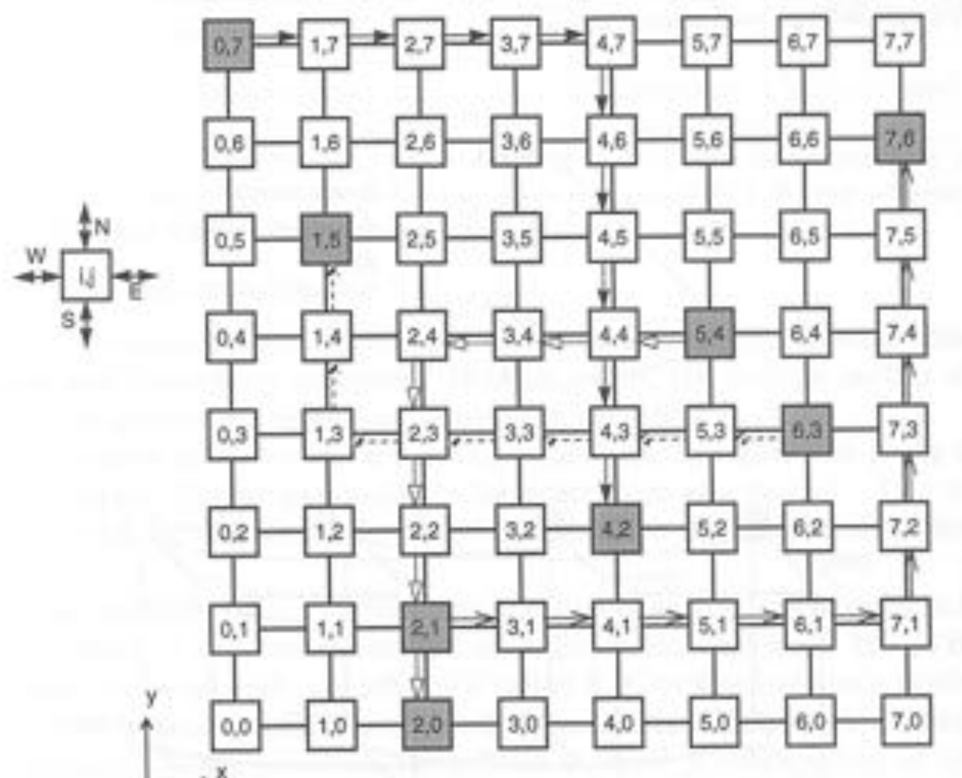


NoC Routing

- NoC Routing Algorithm Attributes:
  - Number of destinations
    - Unicast, Multicast, Broadcast
- Objectives:
  - Maximize throughput: How much load the network can handle
  - Minimize routing delay between source and destination: Minimize hop count

Types of NoC

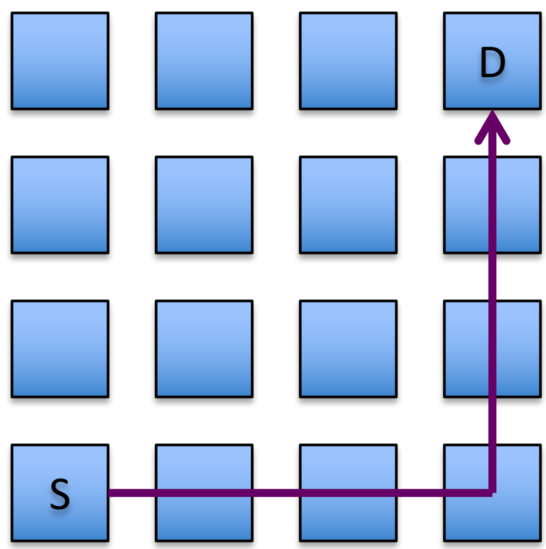
- Deterministic Routing in a 2D-mesh NoC – XY routing
  - the message travels “horizontally” from the source node to the “column” containing the destination, where the message travels vertically.
  - east-north, east-south, west-north, and west-south.



Four (Source; destination) pairs: (2,1;7,6) (0,7;4,2) (5,4; 2,0) (6,3; 1,5)

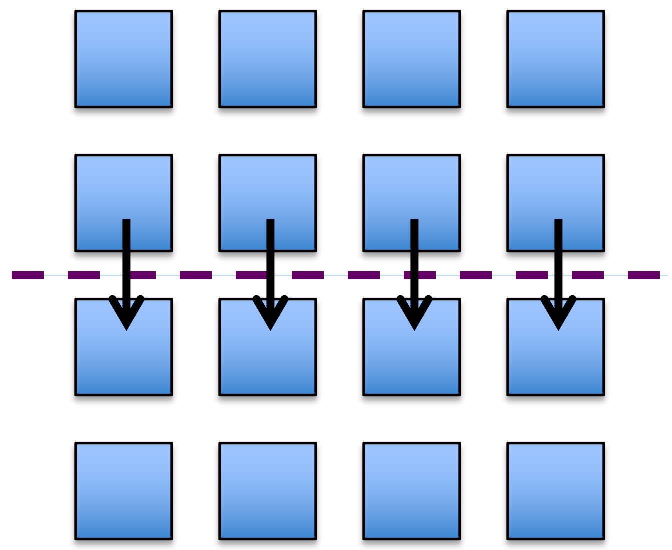
NoC Routing

- Dimension-Ordered Routing (DOR)
  (also called XY routing)



NoC Routing

- DOR (XY) Routing: Traffic crossing bisection uniformly distributed across K channels.



NoC Routing

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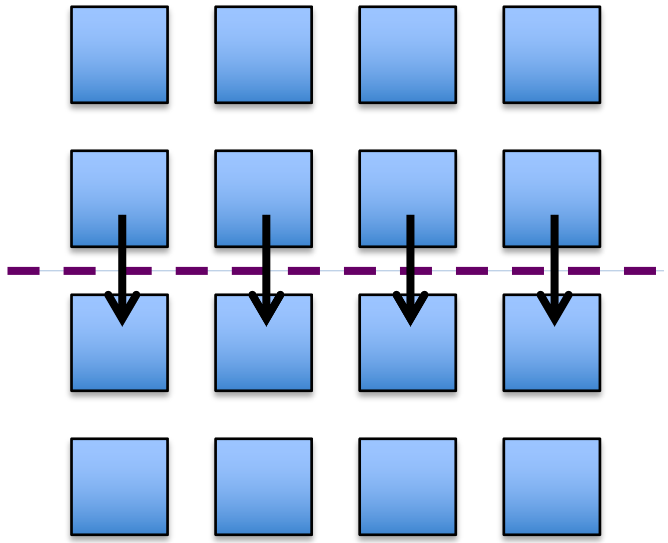
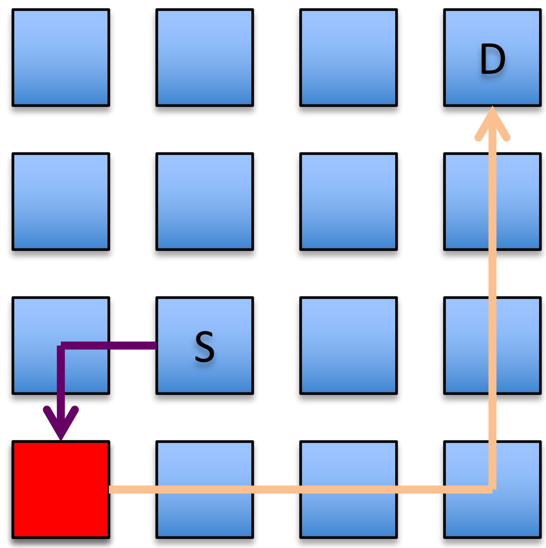


NoC Routing

- Valiant Load-Balancing (VAL)

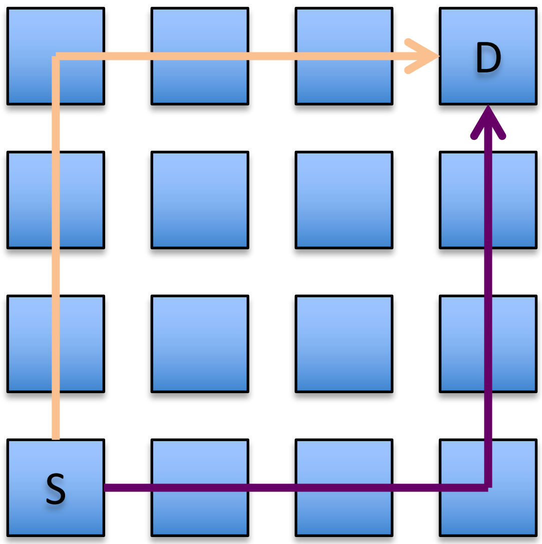
randomly chosen intermediate node



minimal ***XY*** routing to any intermediate node, then minimal ***XY*** routing to destination node

NoC Routing

- O1TURN



use both minimal ***XY*** and ***YX*** routing to the destination
(0.5 ***XY*** + 0.5 ***YX***)

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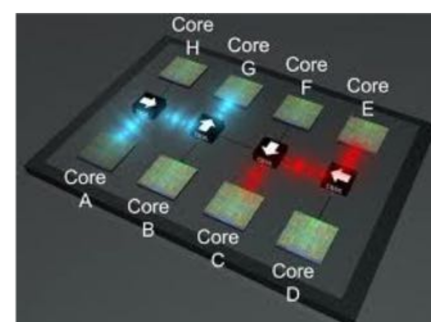
    - Potential Applications
    - Challenging Problems
  - Network on Chips
    - Introduction of NoC
    - Types of NoC
    - Challenging Problems

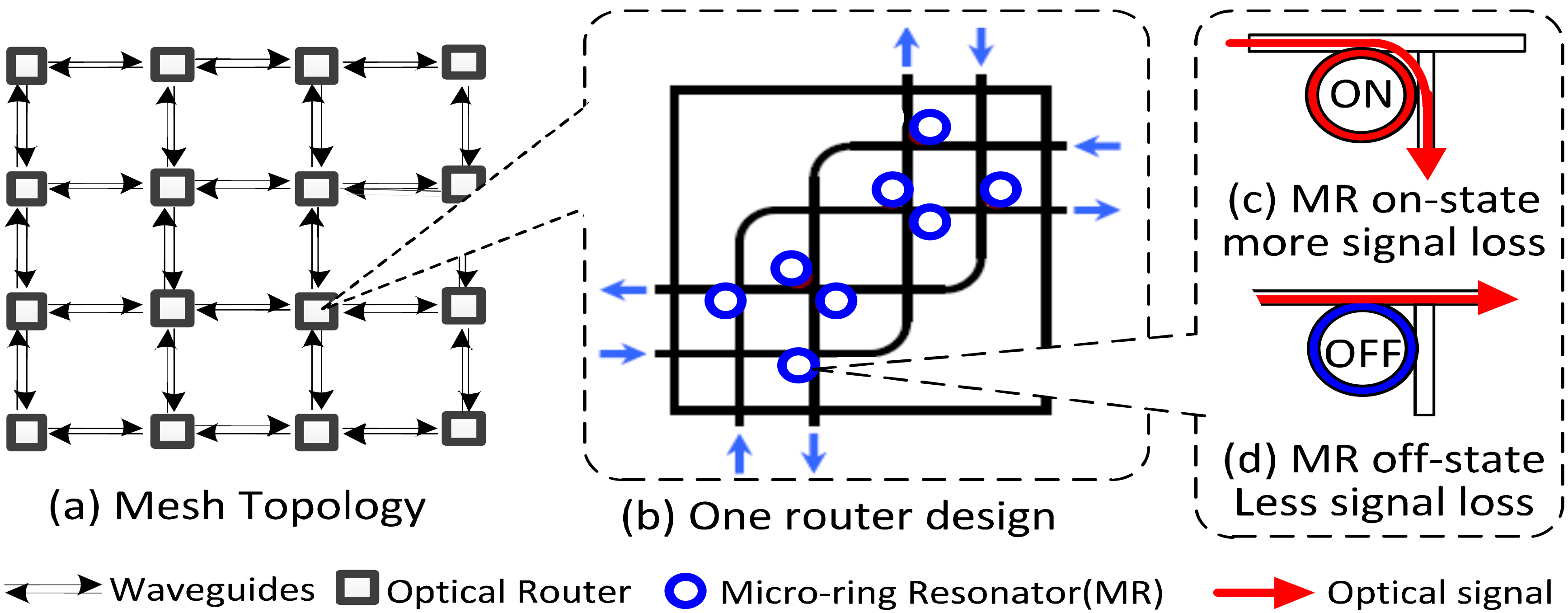
Challenging Problems

- Energy has become one of the primary concerns
  - Energy efficiency doesn't scale with the number of cores; Power consumption grows faster than performance
- On-chip electrical interconnect becomes a primary bottleneck
- Dec. 2012, IBM announced its technology - *silicon nanophotonics*
  https://www.youtube.com/watch?v=LU8BsfKxV2k&list=PLCFC05F2A230A80B5



Challenging Problems

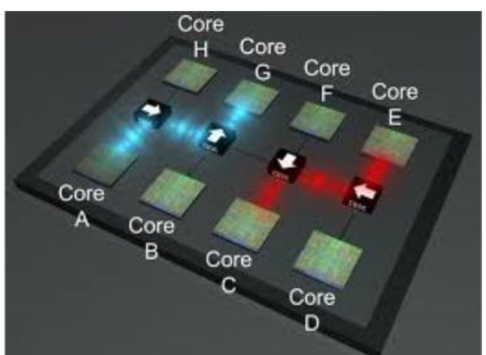
- Characteristics of ONoCs: Bufferless/Concurrent transmission/Special on-chip optical router

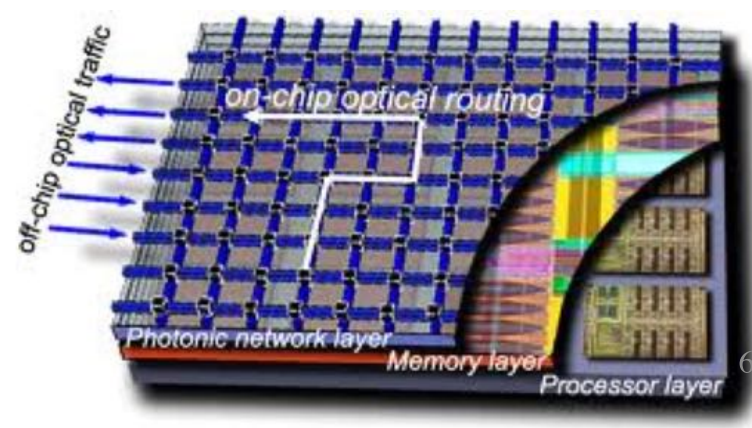


(a) Mesh Topology
(b) One router design

Challenging Problems

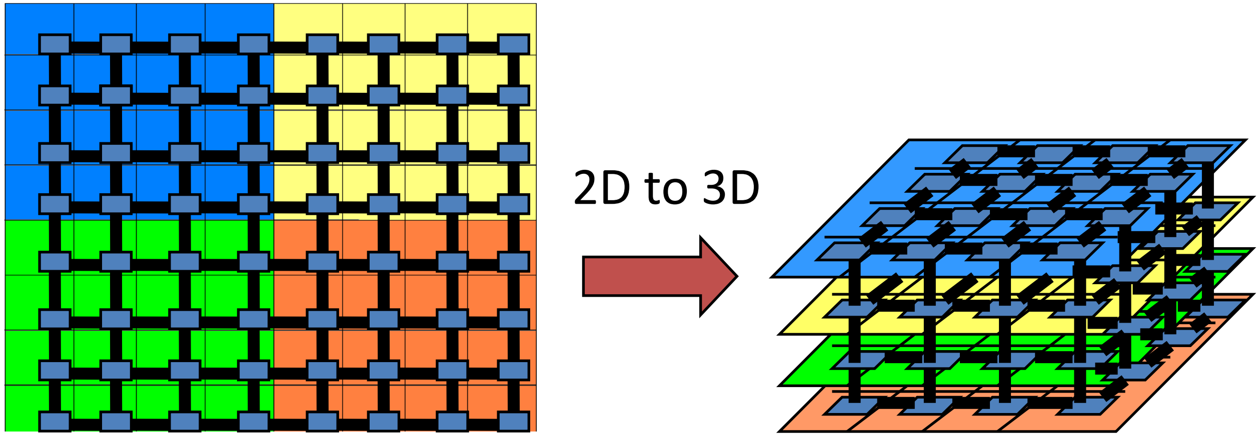
- Jan. 2013, Intel announced the use of a silicon photonic architecture to define the next generation of servers
- Apr. 2013, Intel demonstrated its first inexpensive optical chip
- In 2015, IBM to demonstrate first on-package silicon photonics", Mar 2015





Challenging problems

- Application mapping (map tasks to cores)
- Floorplanning (within the network)
- Buffer sizing (size of queues in the routers)
- Simulation (Network simulation, traffic/delay/power modeling)
- 2D to 3D



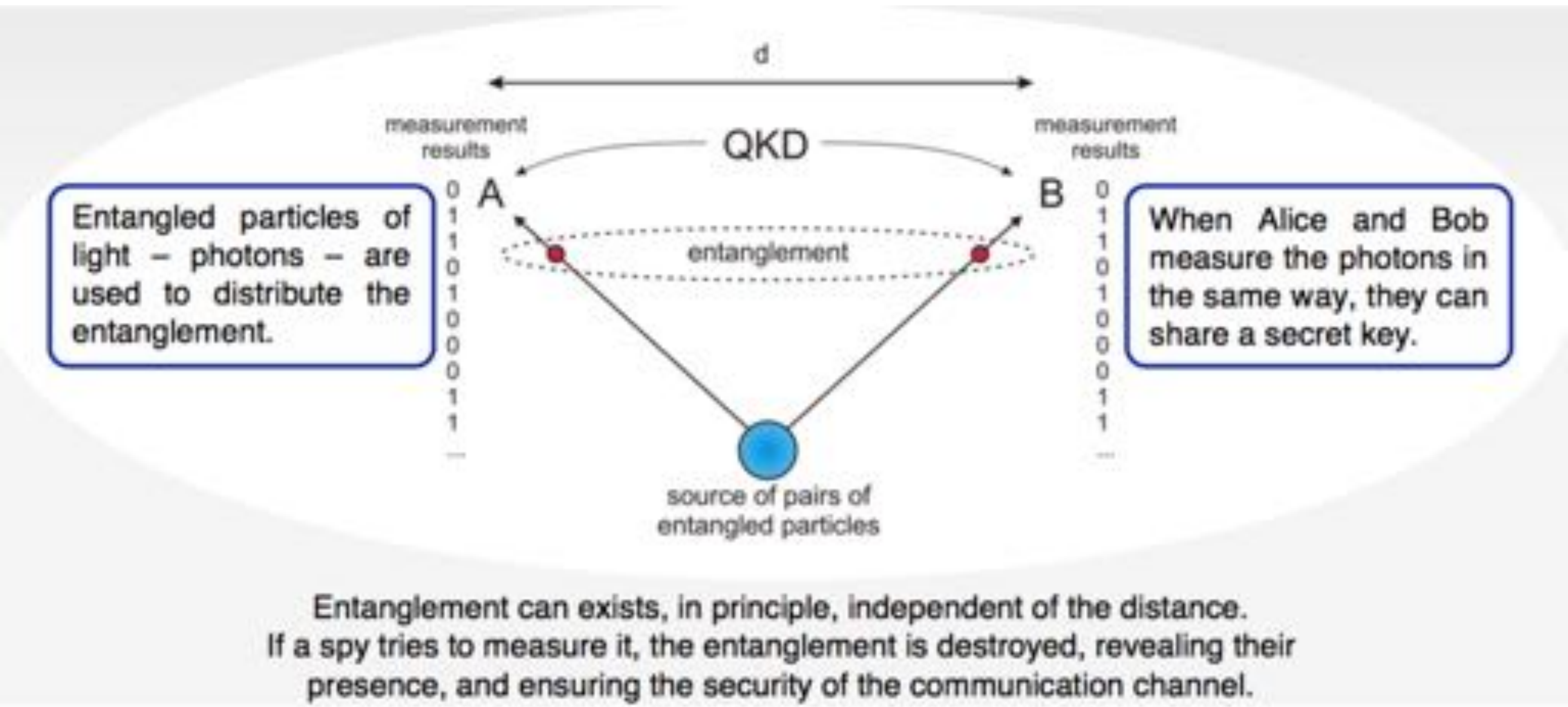
Overview

- This Lecture
  - LiFi
    - What is? How does it work?
    - What are the future applications?
  - Network on Chips
    - What is NoC?
    - What are the types of NoC?
  - Quantum network

Quantum network

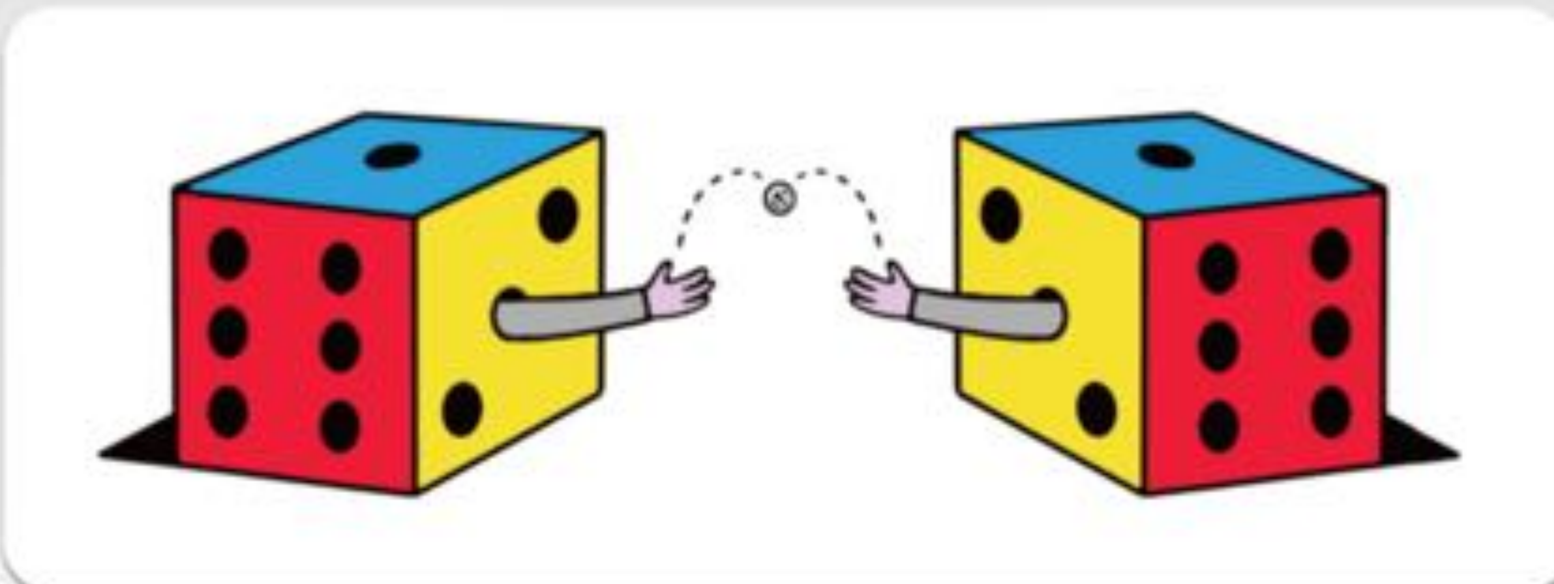
What is Quantum Communication?

Playing with quantum particles to improve today's communication technologies.



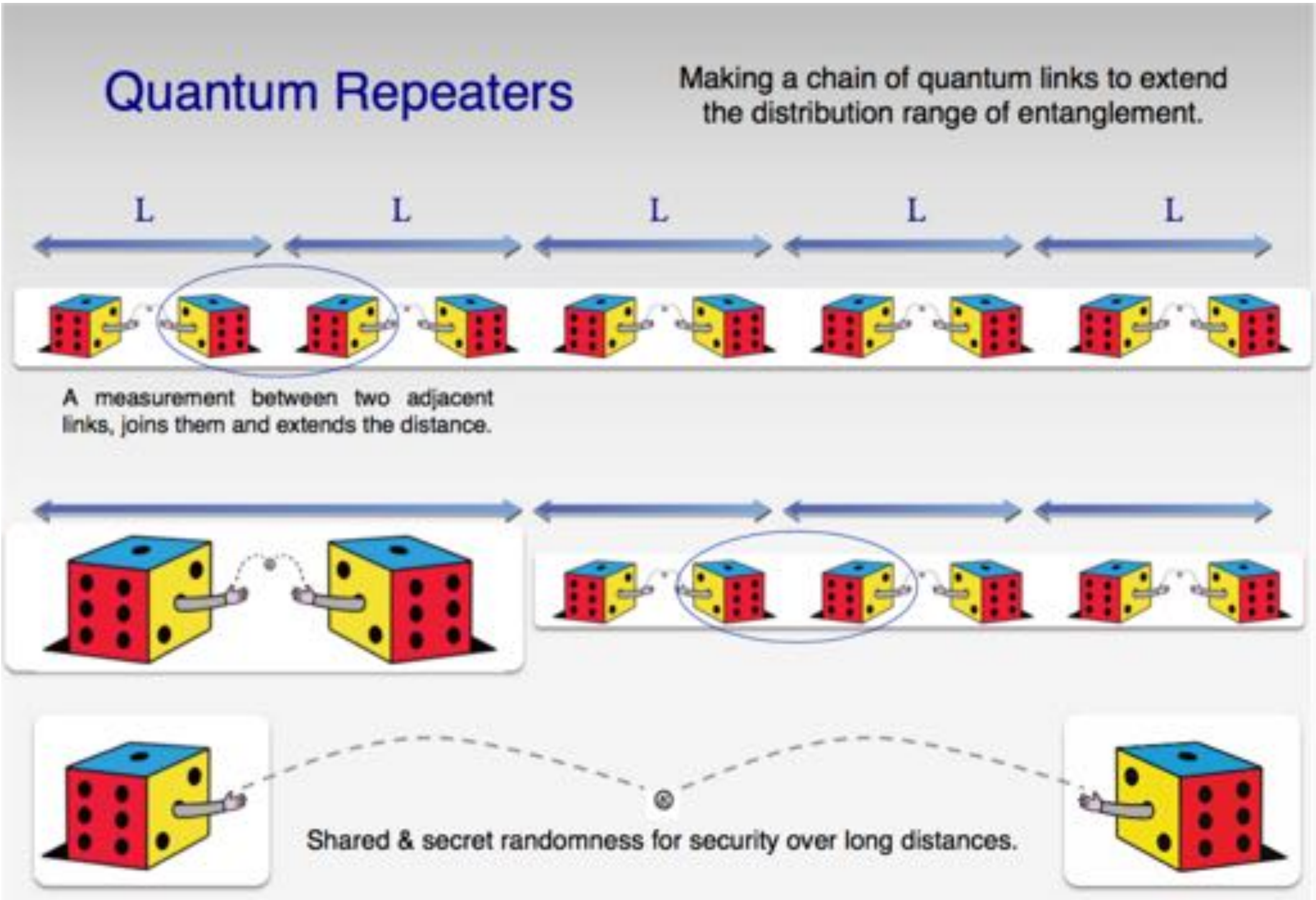
Quantum network

ENTANGLEMENT is like two people tossing a coin at distant locations…

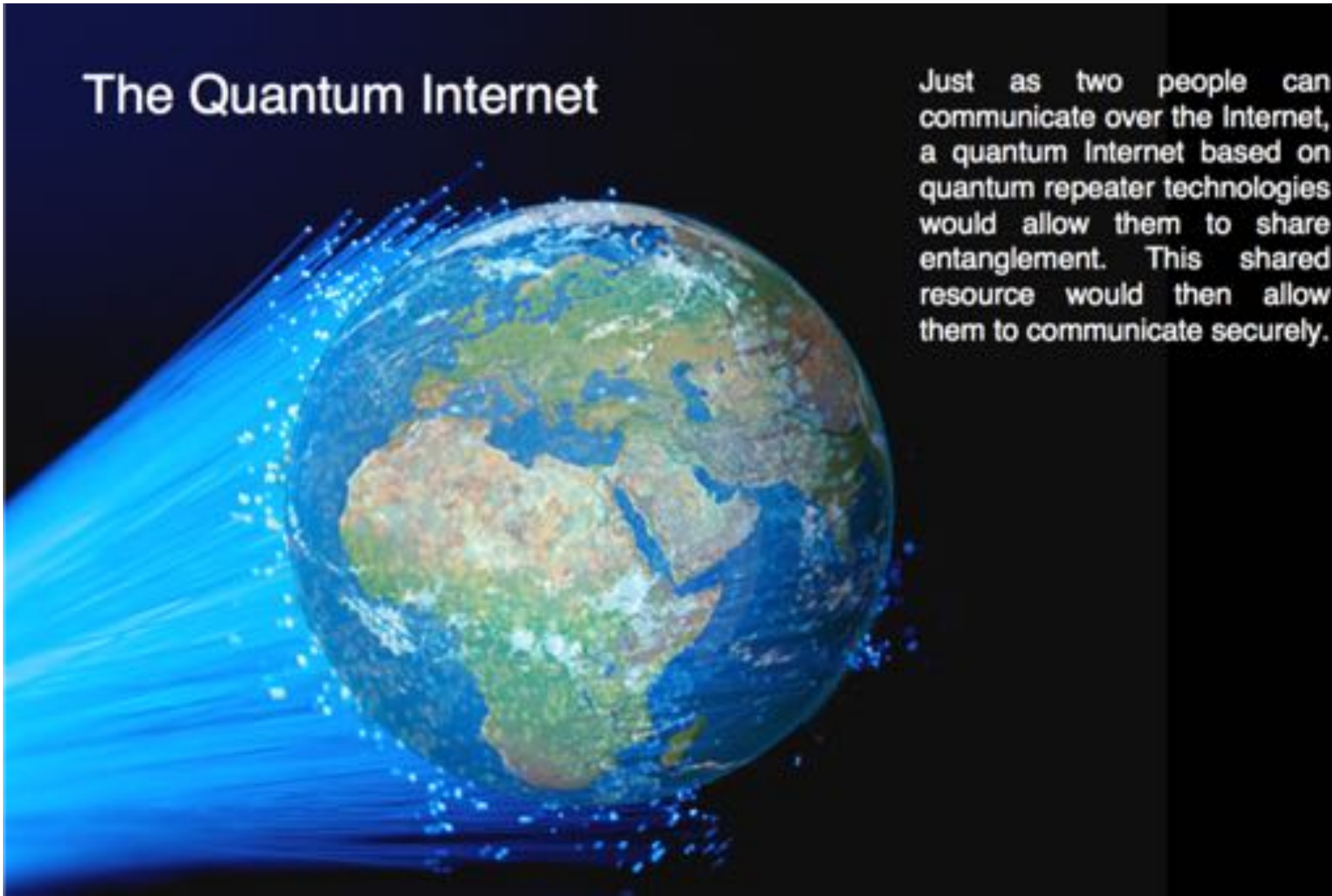


The outcome is completely random, but it is the same outcome in both locations!

Quantum network



Quantum network



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