

Lecture 25 Overview

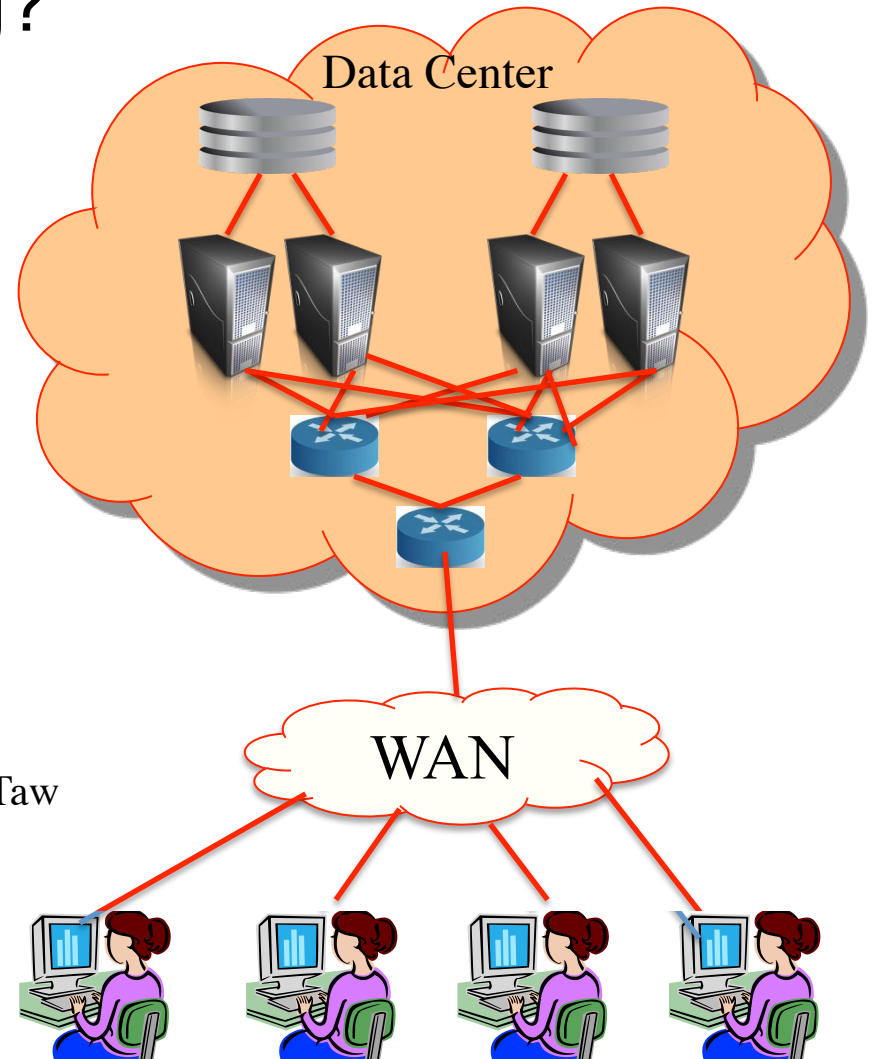
- Last Lecture
 - Cellular Networks
 - MIMO
- This Lecture
 - Advanced networking topics
 - Source: lecture note
- Next Lecture
 - Revision

Cloud Computing

- What is Cloud Computing?



<https://www.youtube.com/watch?v=uYGQcmZUTaw>



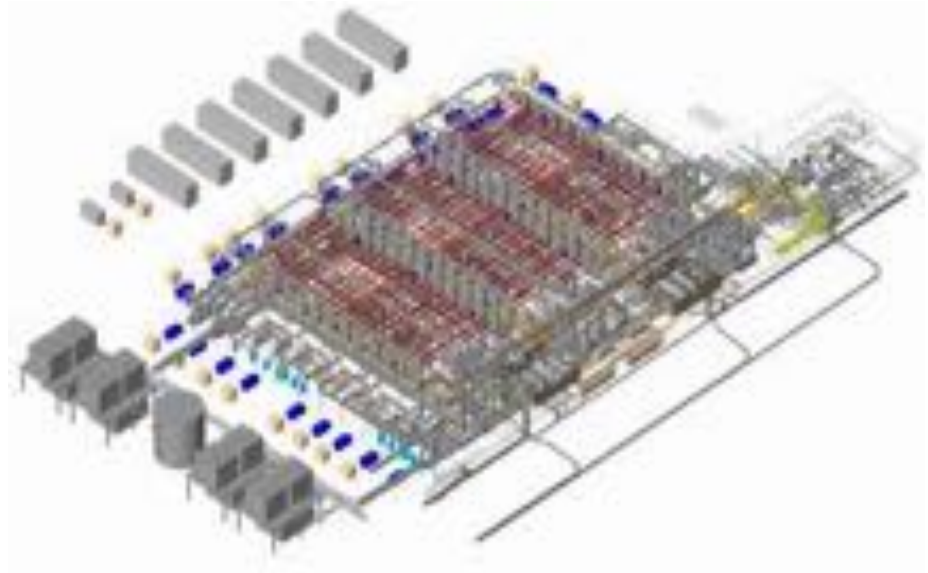
Cloud Computing (cont.)

- What is cloud computing?
 - **Cloud application:** software-as-a-service
 - **Cloud provider:** hardware and software infrastructure that supports the cloud applications
- Benefits of cloud computing
 - Achieve economies of scale
 - Reduce spending on technology infrastructure
 - Reduce capital costs
 - Improve accessibility
 - Less personnel training is needed
 - Minimize licensing new software
 - ...

Cloud Computing (cont.)



<http://www.google.co.nz/about/datacenters/>



How to connect the computing and storage devices
to maximize the performance?

Intra-cloud Network: Data Center Network

- Main components in the data center

- **Servers**

- rack-mount servers
- blade servers

- **Storage**

- Direct Attached Storage (DAS)
- Network Attached Storage (NAS)
- Storage Area Network (SAN)

- **Connectivity**

- L2/L3 switches
- WAN routers



56-Port L2 Switch

40 Ports 10GE/FCoE/DCE, fixed
2 Expansion module slots

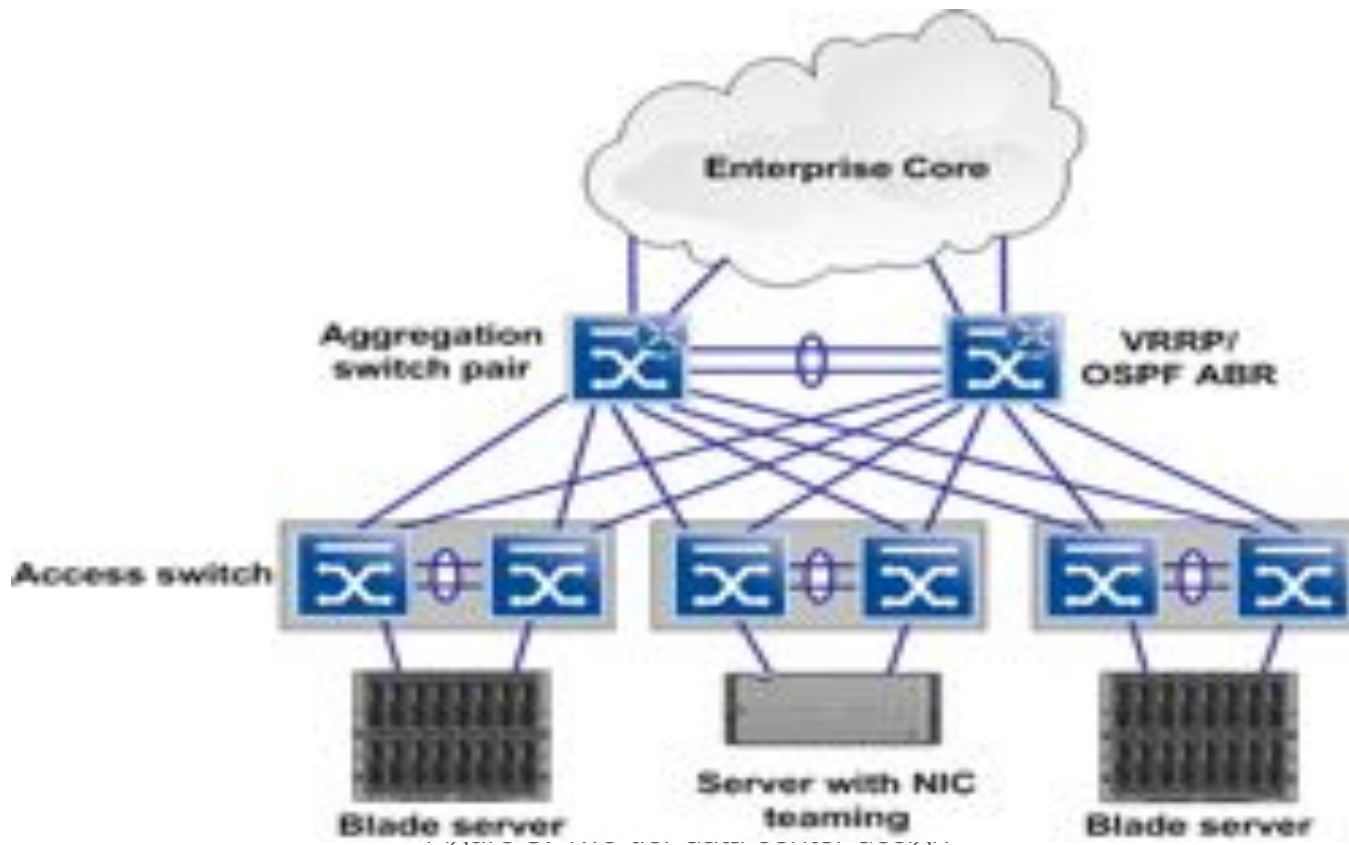


Fibre Channel

8 Ports 1/2/4G FC

Data Center Network Design

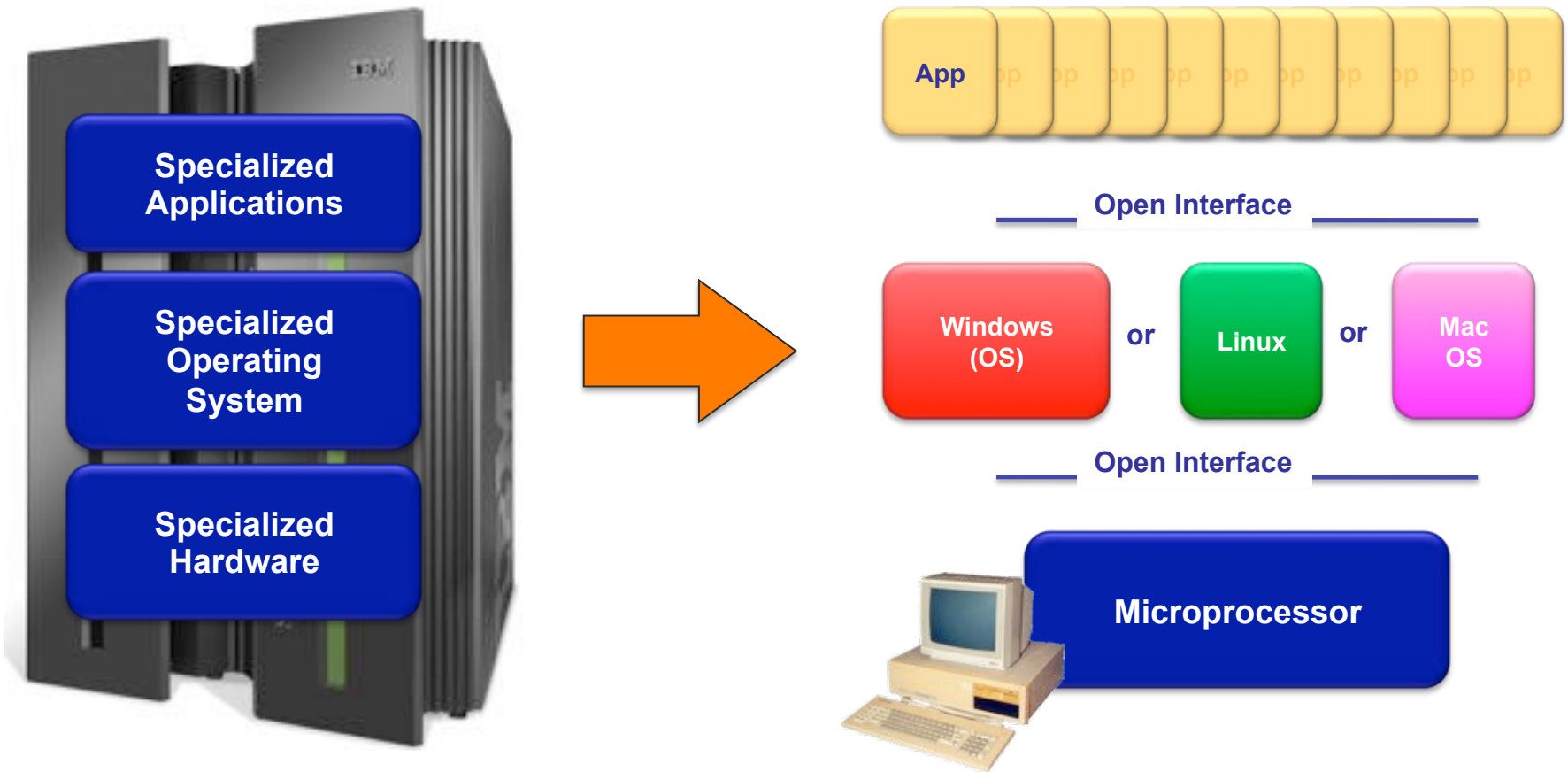
- Two-tier Data Center Design



Limitations of Current Network Architecture

- Hard to manage
 - expensive, buggy software in equipment, cascading failures
- Closed equipment
 - Software bundled with hardware
 - Vendor-specific interfaces
 - Slow process in deploying new capabilities
- Inconsistent policies
 - have to configure thousands of devices and mechanisms
- Inability to scale
 - hundreds or thousands of network devices that must be configured and managed

Limitations of Current Network Architecture

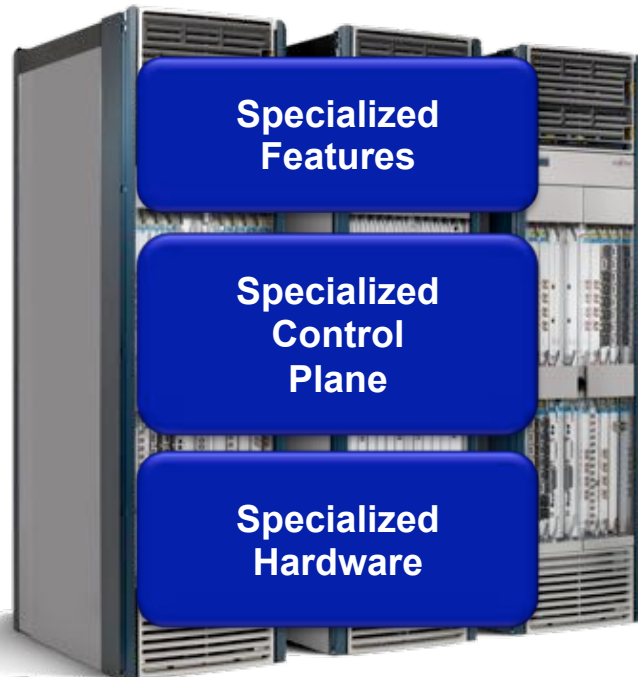


Vertical

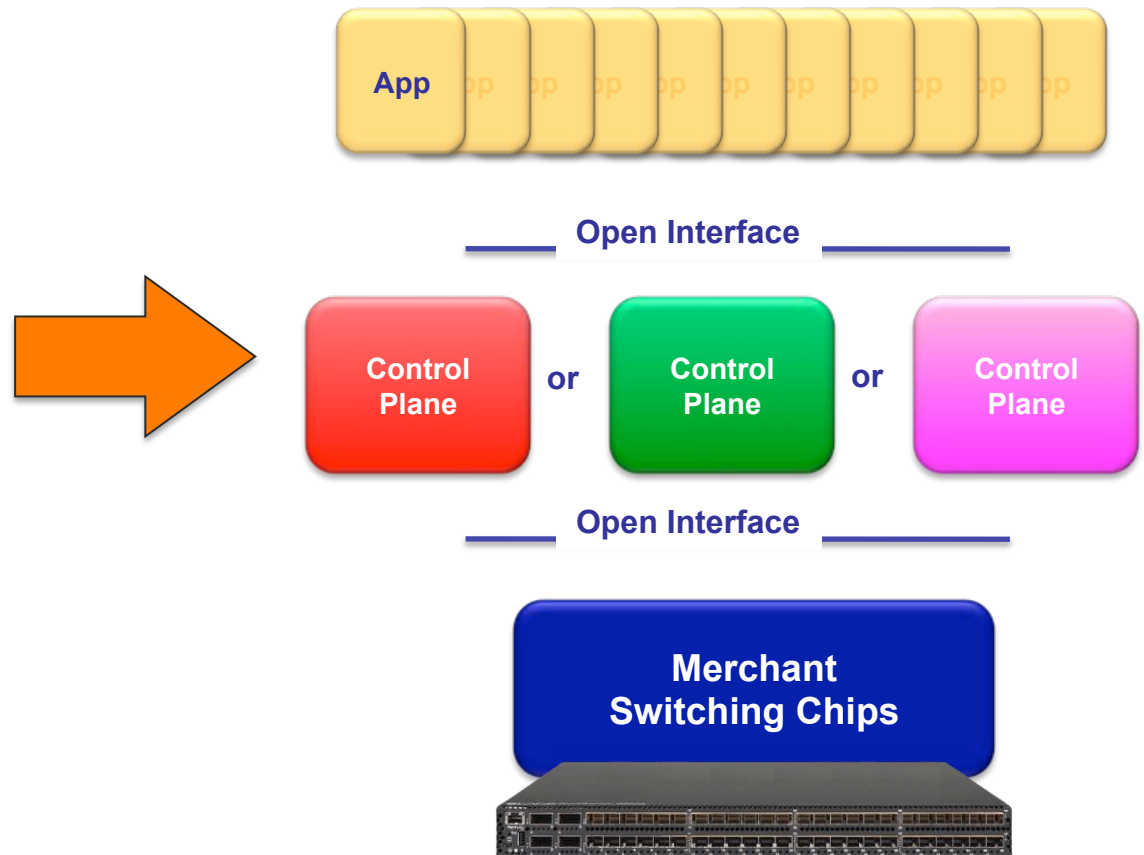
Need for New Network Architectures

- Changing traffic patterns
 - Client-server to enterprise data center
- Consumerization of IT
 - accommodate these personal devices in a fine-grained manner while protecting corporate data and intellectual property.
- The rise of cloud services
 - cloud services must be done in an environment of increased security, compliance, and auditing requirements
- Big data means more bandwidth
 - mega datasets requires massive parallel processing on thousands of servers

Need for New Network Architectures

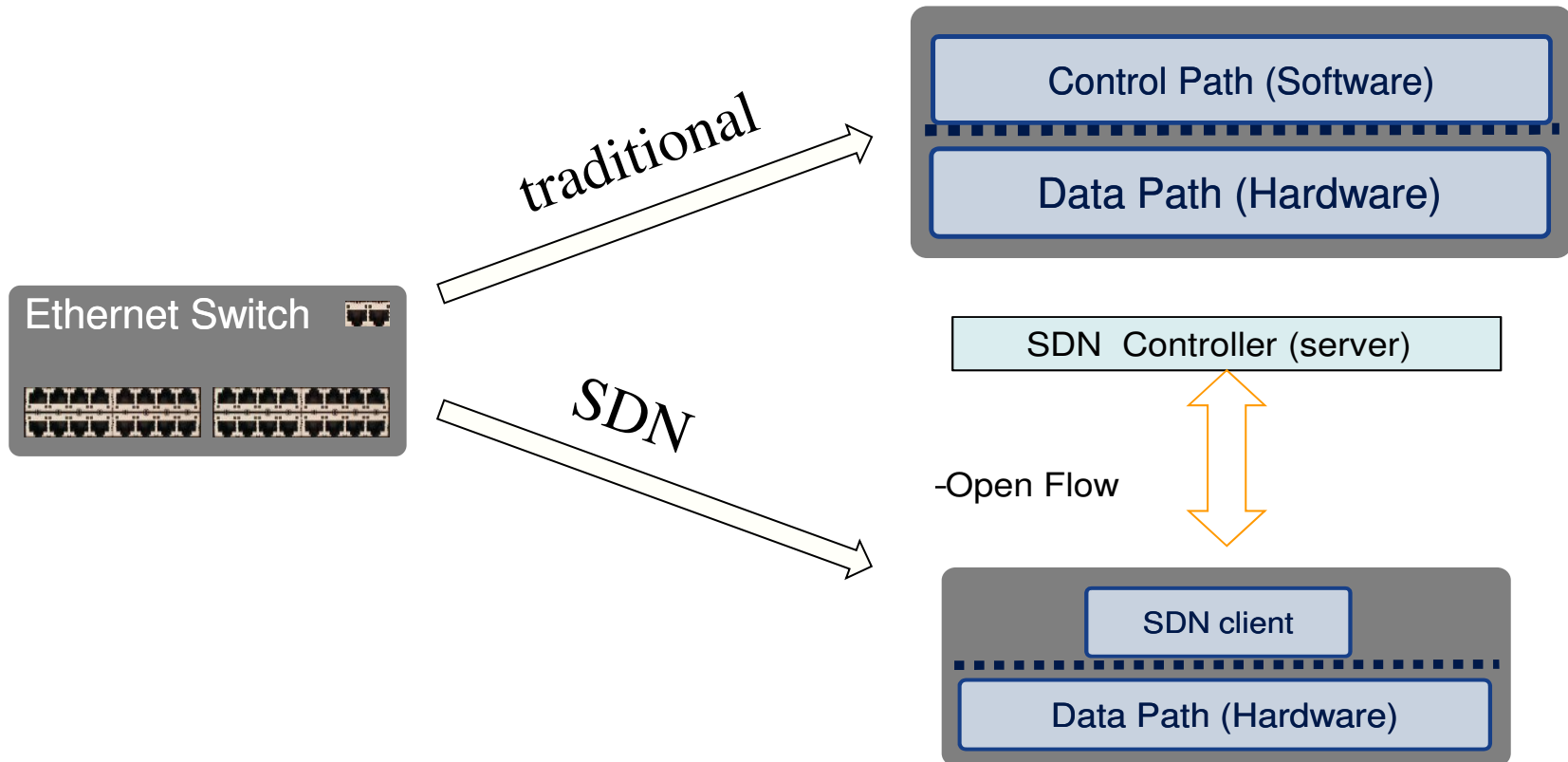


Horizontal

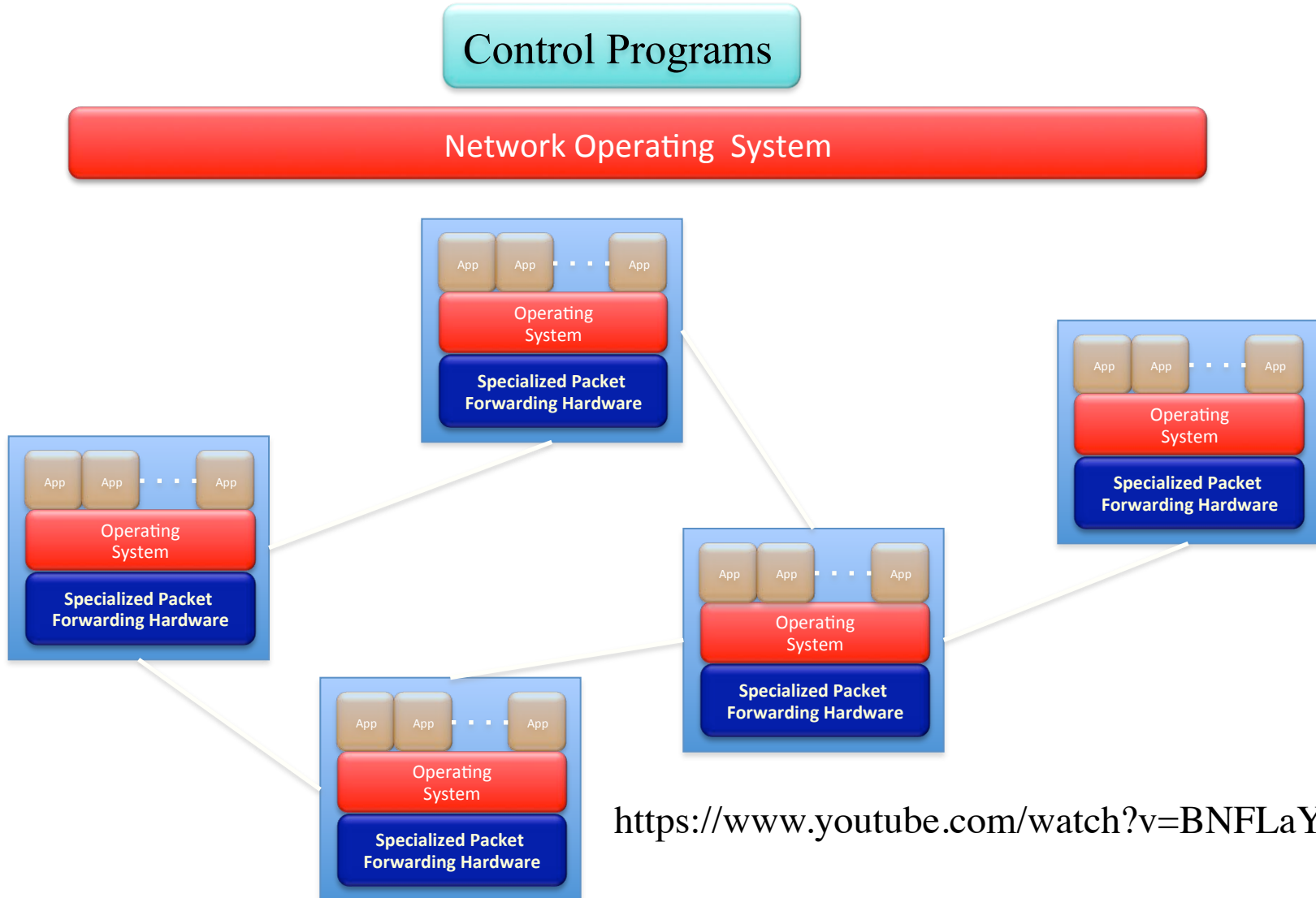


Software Defined Networking

- Decouple network control and forwarding functions
- Allow administrators to manage network services through abstractions of lower level functionality.

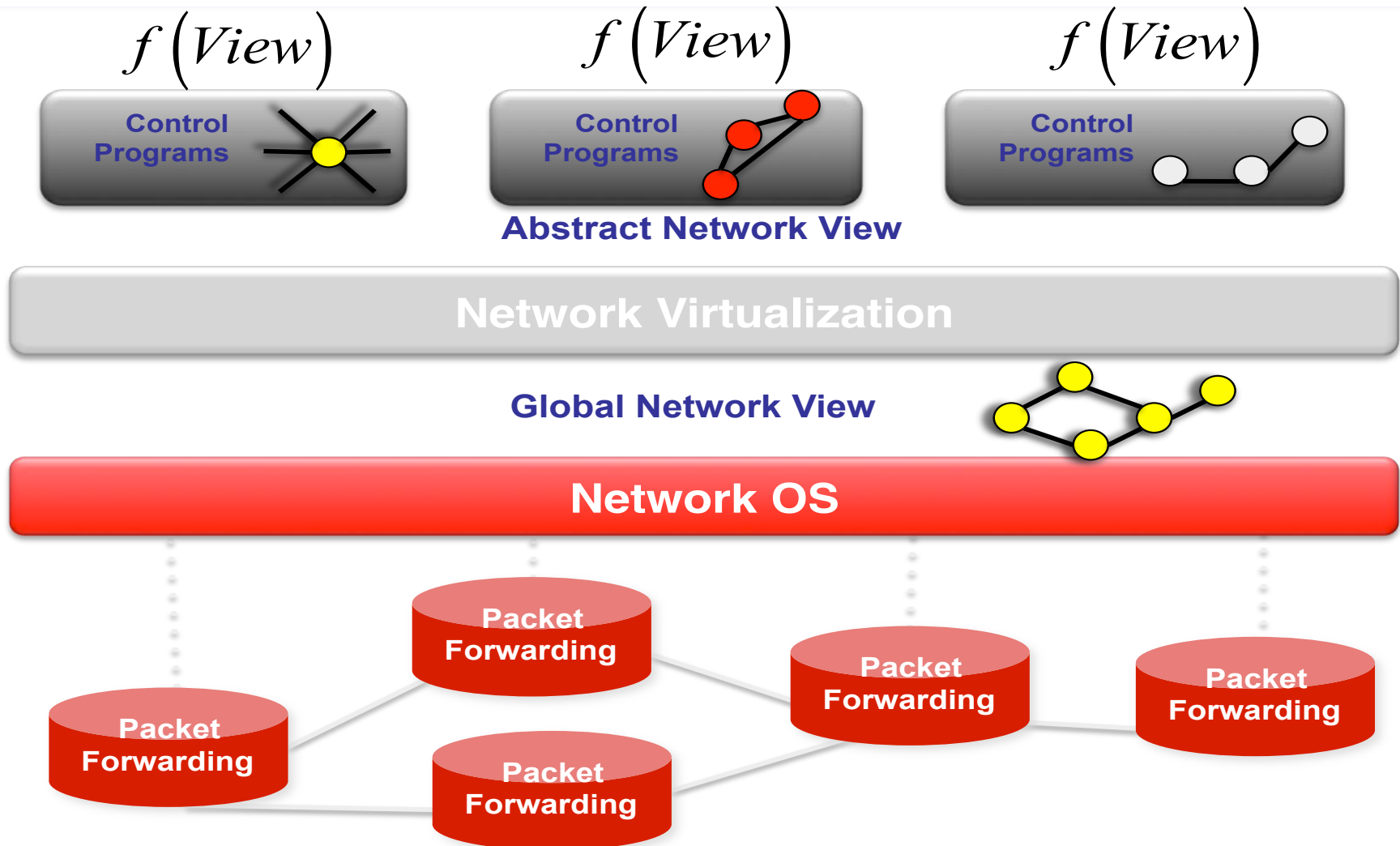


What is SDN? An OS for Networks



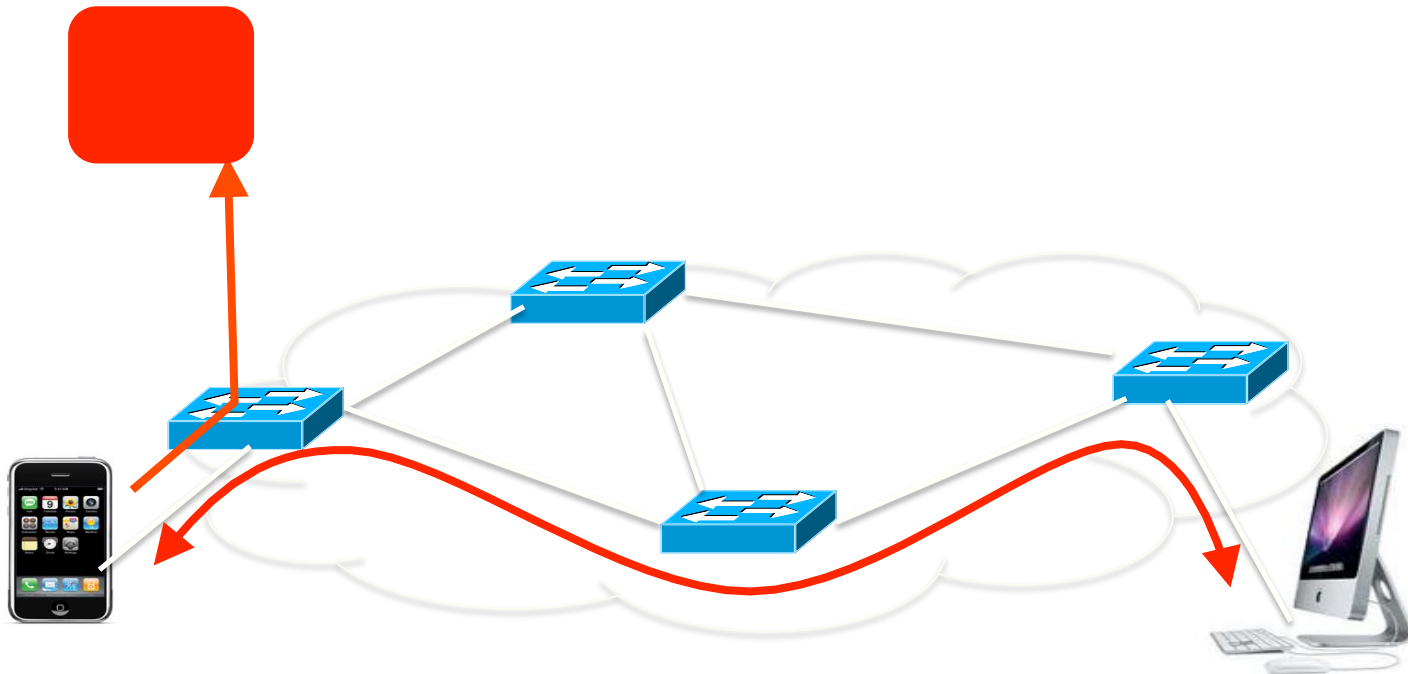
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Software Defined Networking



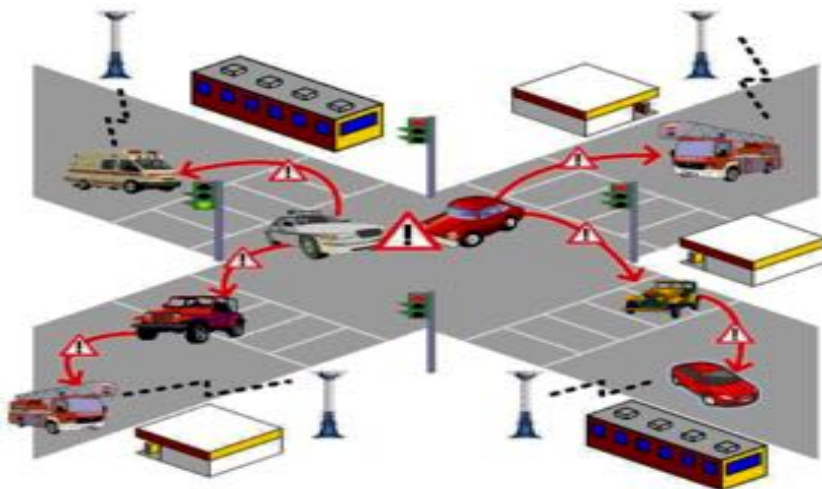
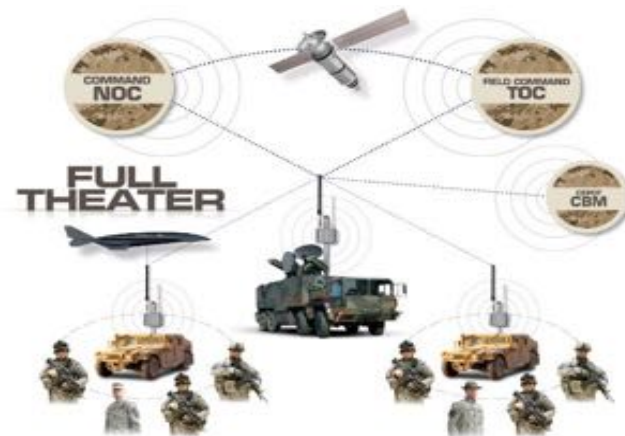
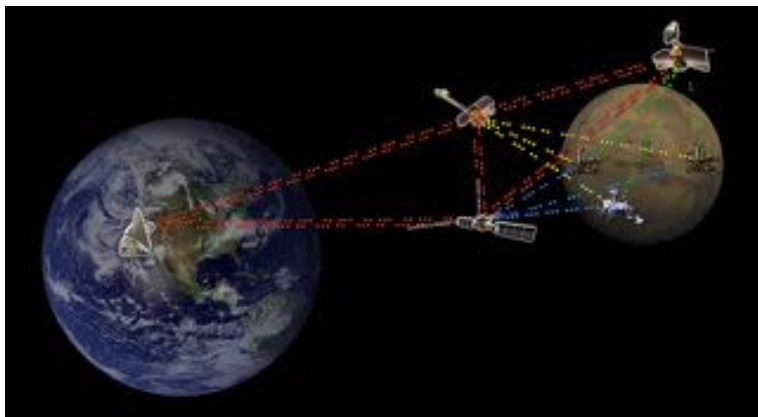
OpenFlow

- A communication protocol that gives access to the forwarding plane
- Allows remote administration of a switch's packet forwarding table.



Challenged Networks

- Networks may operate poorly in environments characterized by very long delay paths and frequent network partitions.

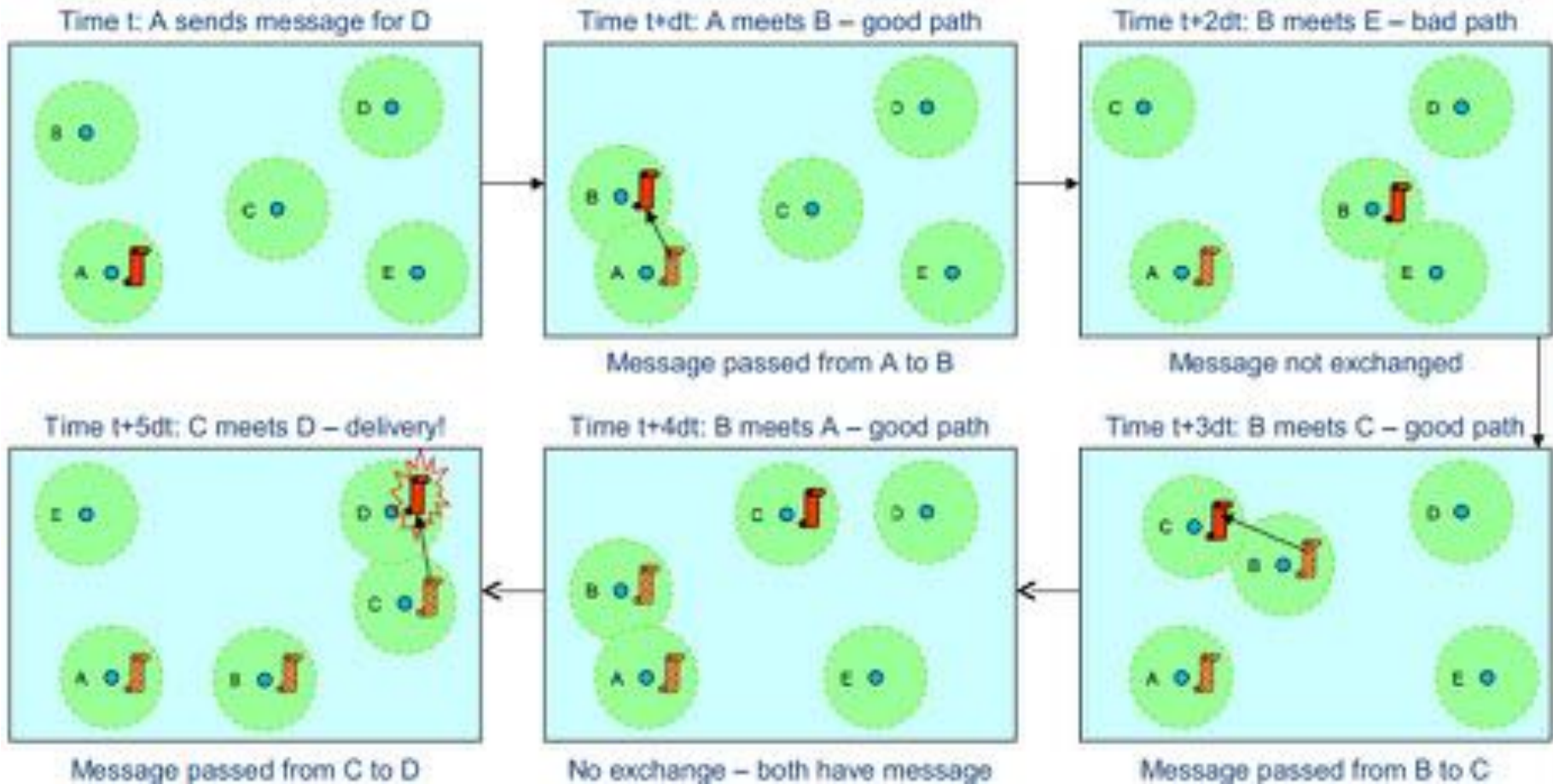


Delay-tolerant Networking (DTN)

- A network architecture that seeks to address the technical issues in heterogeneous networks that may lack continuous network connectivity.
- Key properties of DTN
 - **High Latency:** Any two nodes may never meet each other.
 - **Low Data Rate:** Due to the long latency of data delivery.
 - **Disconnection:** It is hard to find an end-to-end path.
 - **Long Queuing Delay:** Because of the disconnection.
 - **Short Range Contact:** Only one-hop communication is guaranteed.
 - **Dynamic Network Topology:** Different types of user behavior will result in dramatically different network conditions.

Routing in DTNs

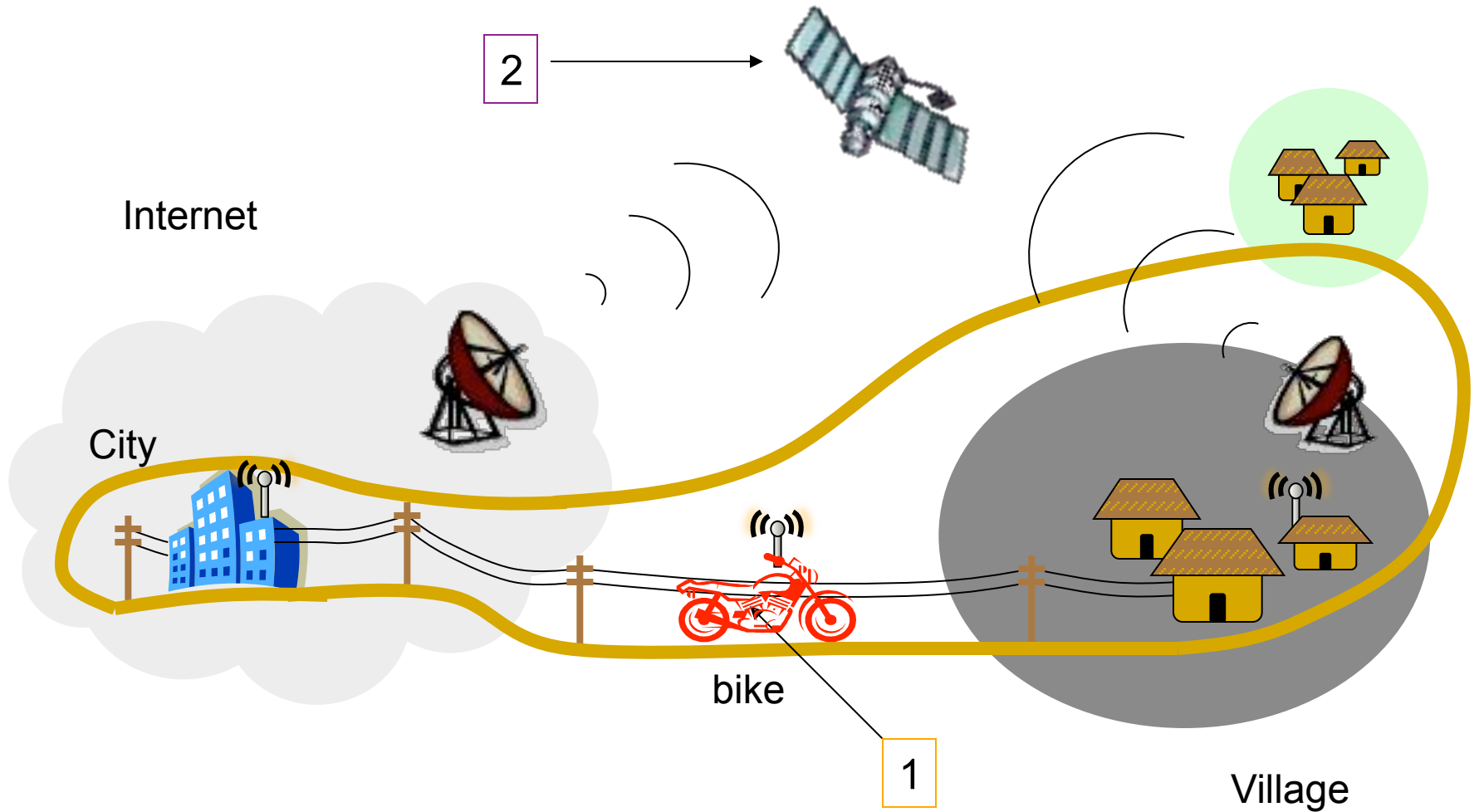
Store – Carry -Forward



DTN-based Social Network

- DTN-based Short Message Service
- Example: A lecturer can send a advertisement message to his students, and the students can help to propagate the message through the social network to their friends, roommates, etc.
- Benefit
 - A more convenient way to find and exchange information than traditional face-to-face communication
- Challenge
 - Need to find incentive mechanisms to convince end user to use the system

Email Delivery for Remote Area



Google's Balloon Network



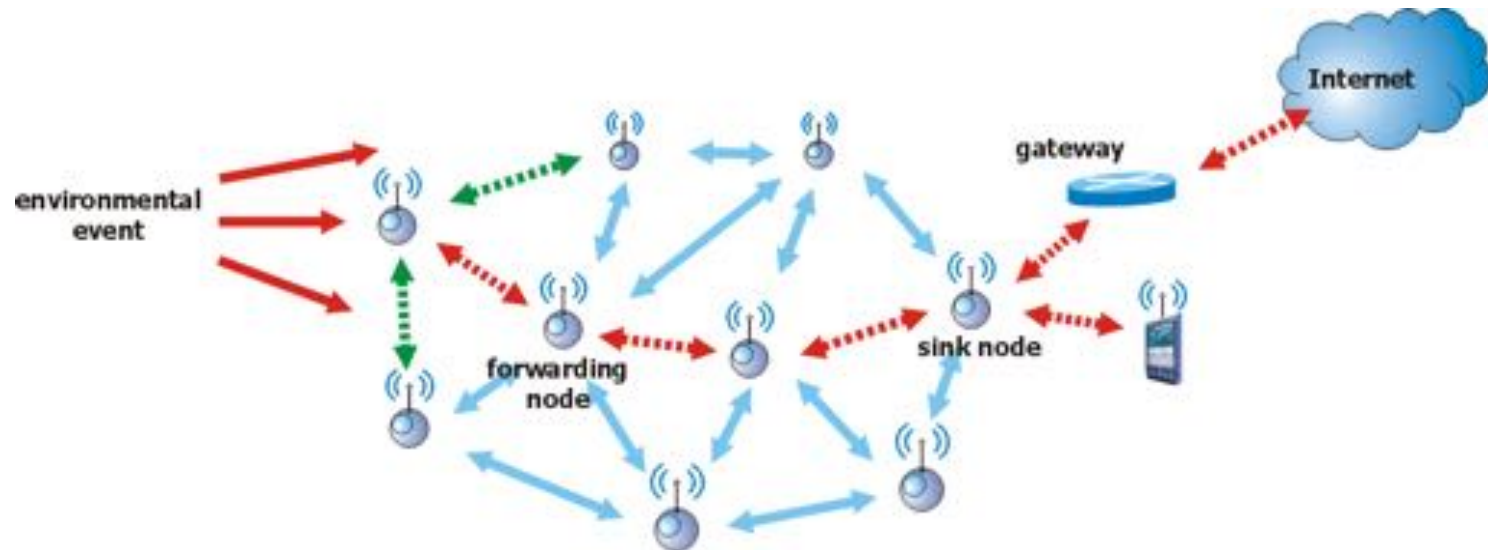
<http://www.google.com/loon/>



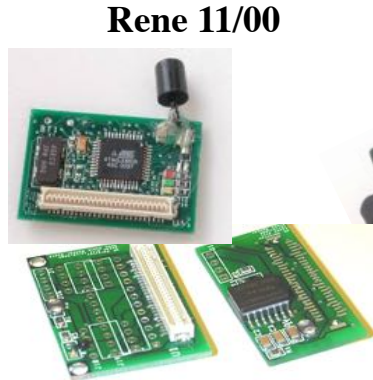
Wireless Sensor Network

“Sensor networks are massive numbers of small, inexpensive devices pervasive throughout electrical and mechanical systems and ubiquitous throughout the environment that monitor and control most aspects of our physical world.”

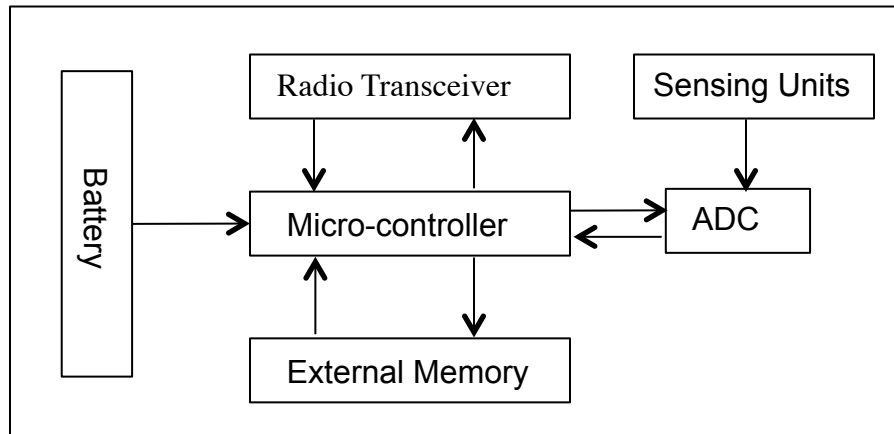
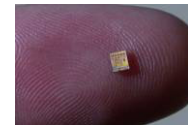
National Research Council



Hardware



Spec 6/03
“Mote on a chip”



Sensor Node Architecture

Sensing Unit:

- ☐ Temperature
- ☐ Humidity
- ☐ Light
- ☐ Pressure
- ☐ Image
- ☐ 3D coordinates
- ☐ ...

Features & Challenges

- Tight resource constraints
 - Limited battery power
 - Limited computation capability
 - Limited memory
 - Limited bandwidth



Mini Type Year	Mini 1999	Mini 2 2000	Mini 2000	Mini 2000	Mini 2 2002	Mini 2 2002	Mini 2004
Microcontroller	AT90C5533		ATmega163		ATmega128		ATMSP430
Type	8		16		128		40
Program memory (Kb)	0.5		1		4		2
RAM (Kb)	15		15		8		3
Active Power (mW)	45		45		75		6
Sleep Power (uW)	1000		36		100		6
Wakeup Time (us)							
Non-volatile storage							
Chip	24LC256		AT40C0041H		AT24C015		
Connection type	I ² C		SPI		I ² C		
Size (Kb)	32		512		128		
Communication							
Radio	TR1000		TR1000		CC1000		CC2420
Data rate (kbps)	10		40		18.4		250

Applications(cont.)

Smart House



Applications(cont.)

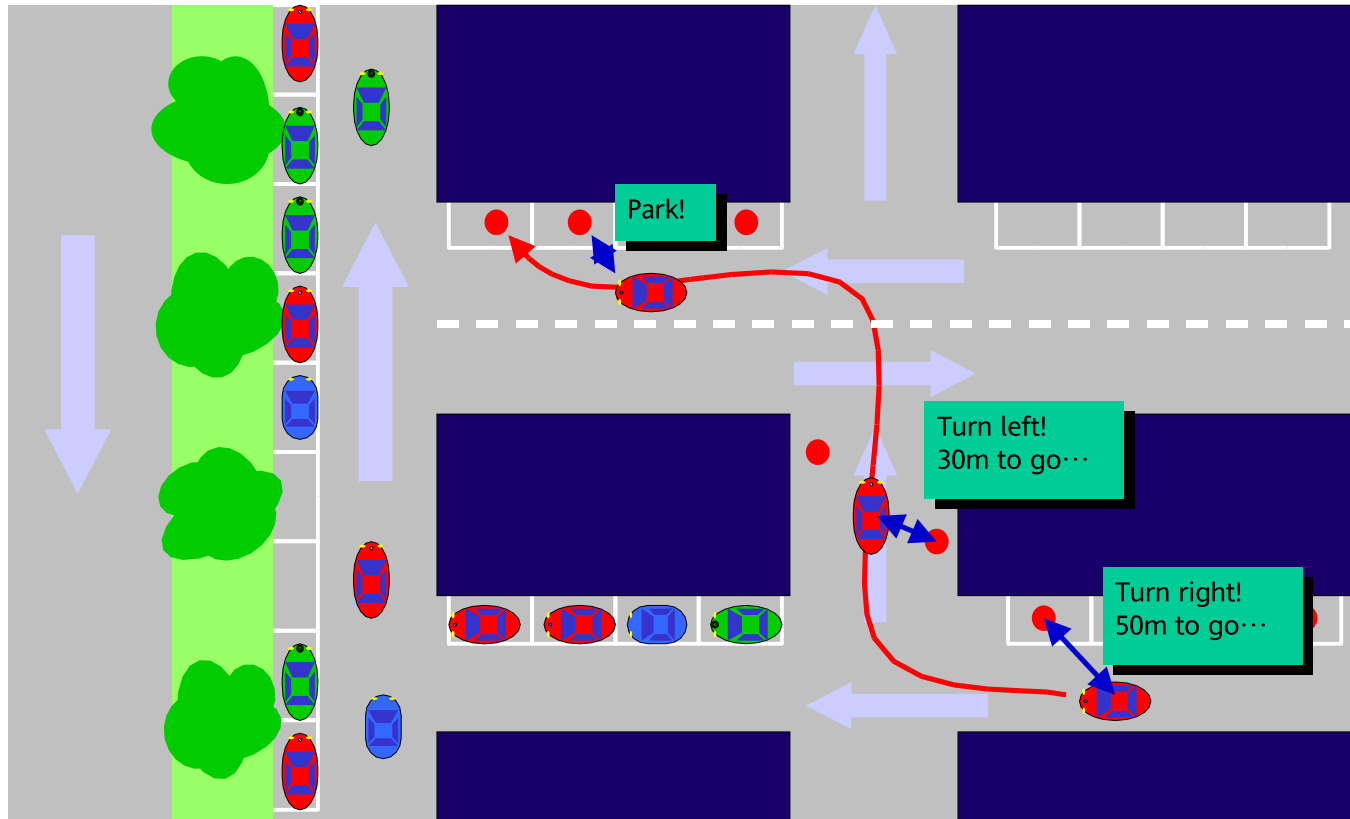


Traffic Control & Intelligent Transport



Applications(cont.)

Smart Park



Internet of Things

“A network of items—each embedded with sensors—which are connected to the Internet.”
-- IEEE

Sensor devices are becoming widely available



Linker Intel Group



Image Sensor Device



Internet of Things

Intelligent Systems for a More Connected World

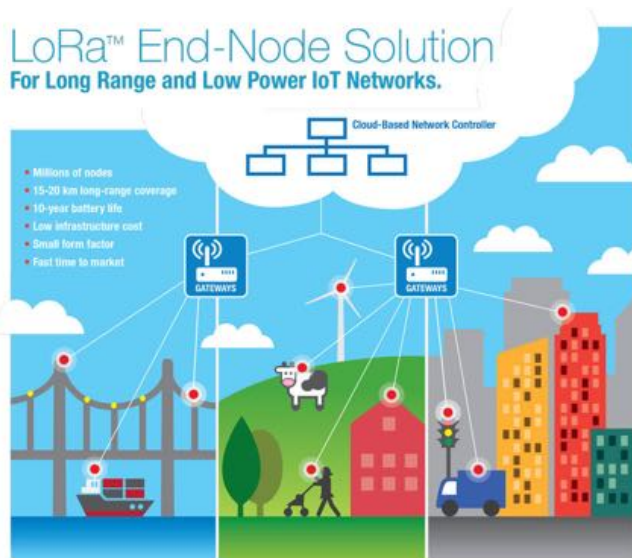
WHAT ARE INTELLIGENT SYSTEMS?

Intelligent Systems are devices that transform how we travel, shop, make things and more.

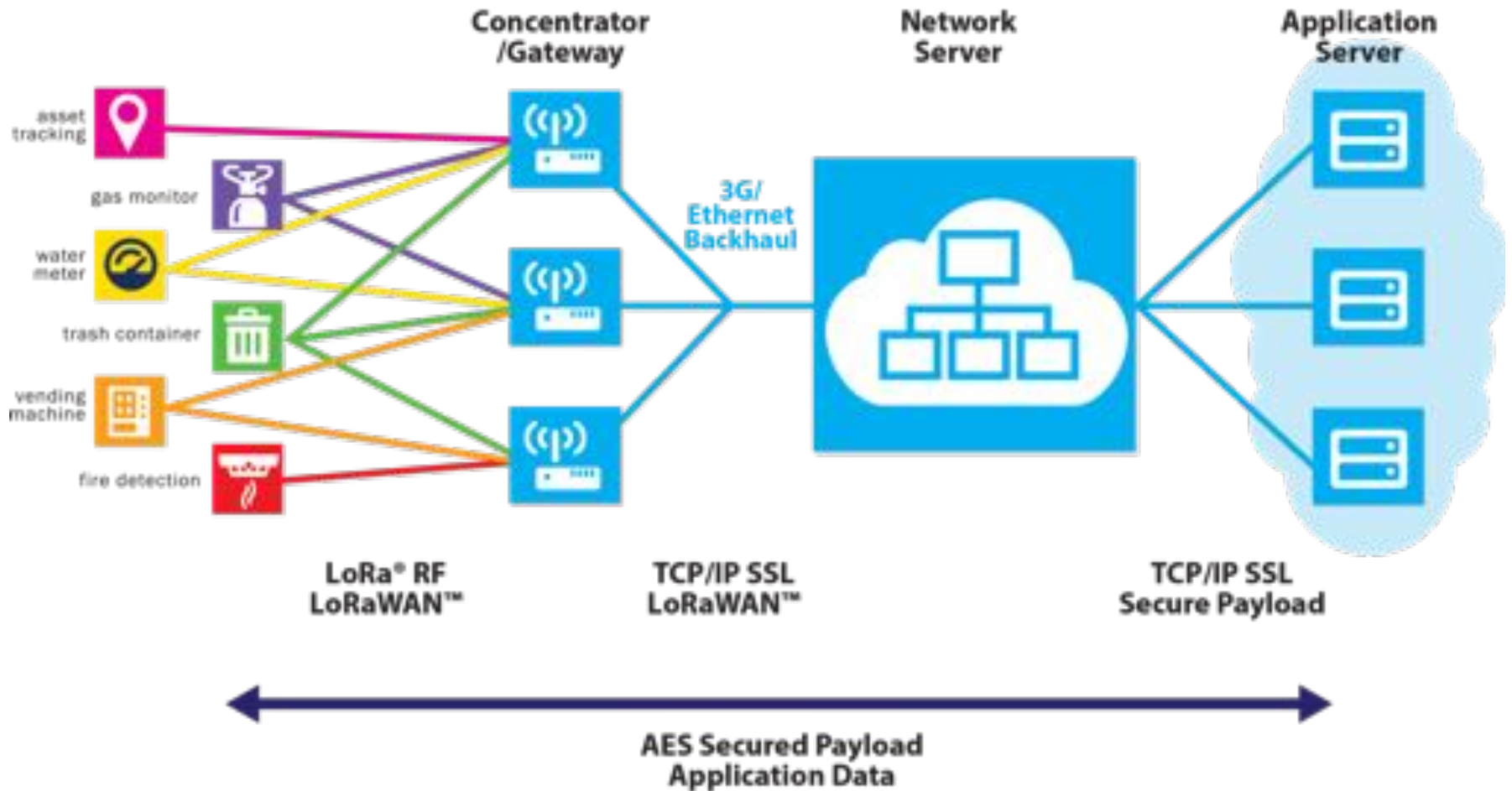


Low Power Wide Area Network (LPWAN)

- A physical layer or wireless modulation for IoT
 - Long range communication (> 10 km in rural areas)
 - Robust communication (Chirp Spread Spectrum)
 - Low power (> 10 years battery life)
 - Large network capacity (a large number of nodes in a network)

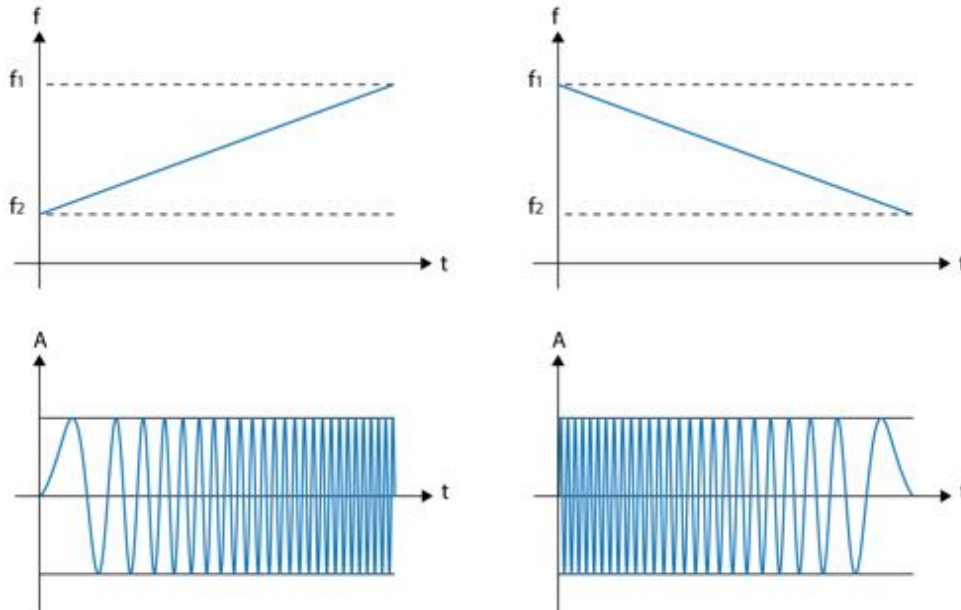


Architecture



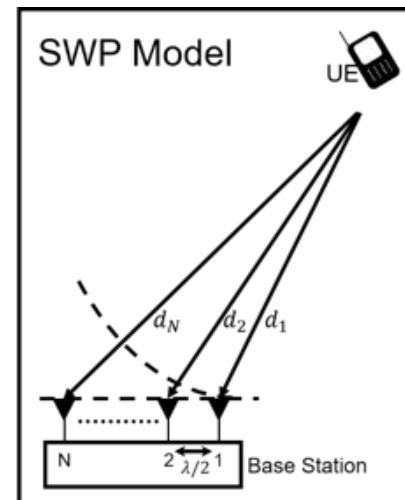
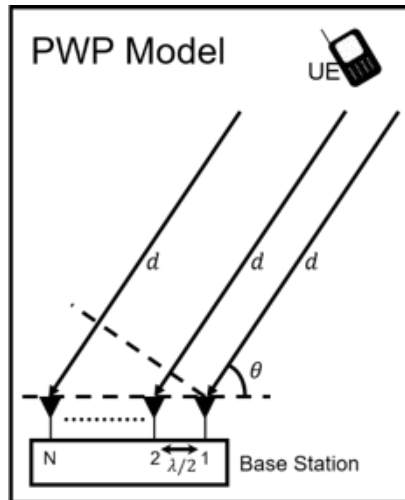
LoRa Technology

- A patented wireless communication technology
 - developed by Cycleo of Grenoble, France
 - Acquired by Semtech in 2012.
- Chirp Spread Spectrum
 - A chirp is a signal in which the frequency increases (up-through time in a very linear way.



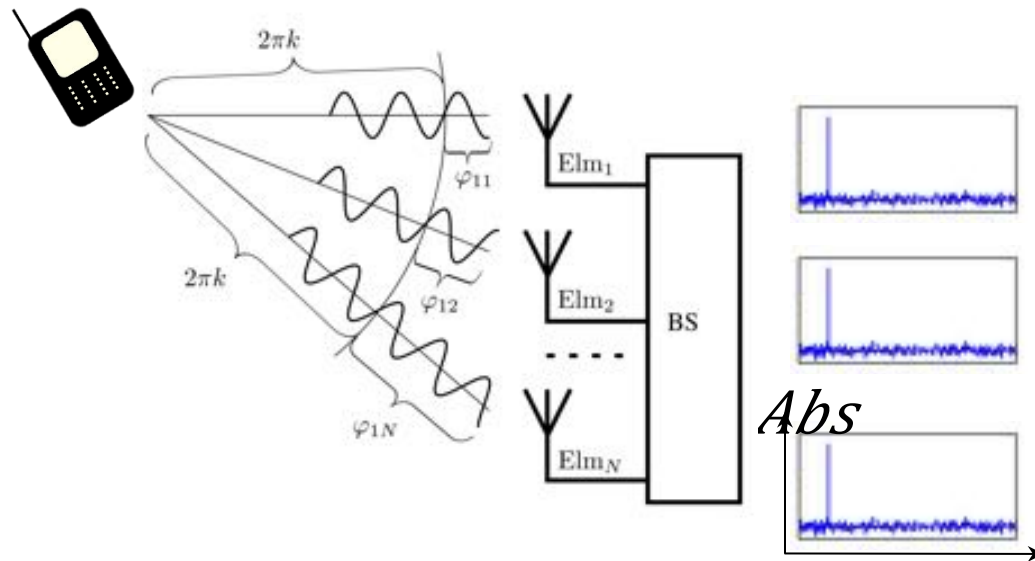
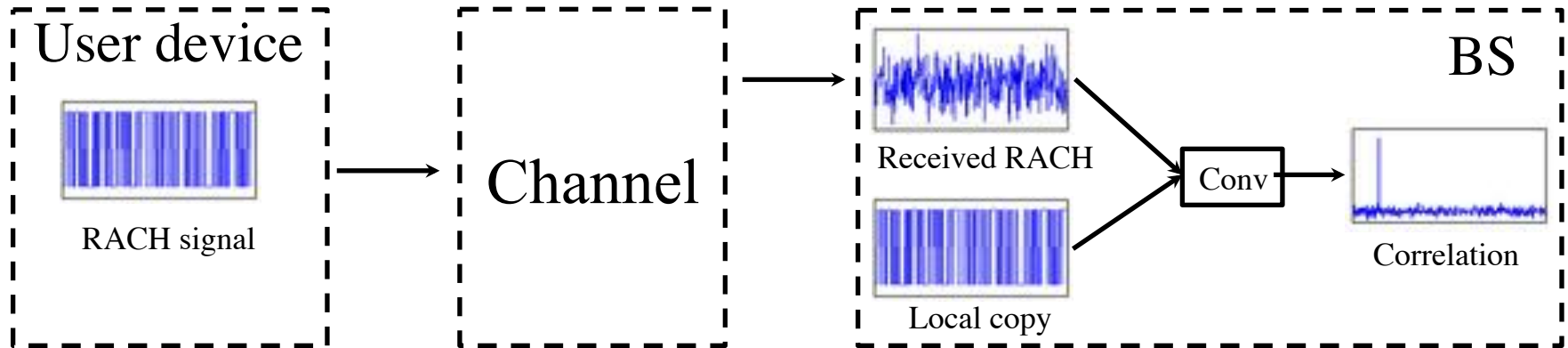
User Localization using Massive MIMO

- Difference between plain wave propagation (PWP) and spherical wave propagation (SWP)



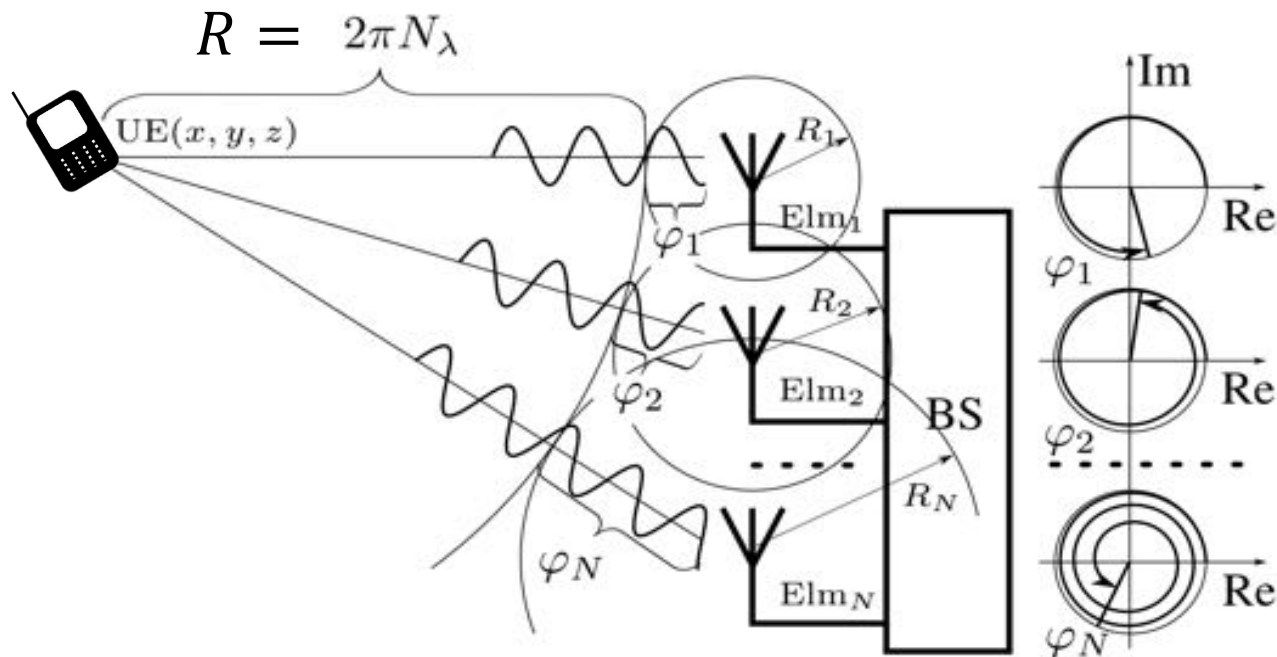
User Localization: Key idea

- Random Access Channel (RACH) synchronization



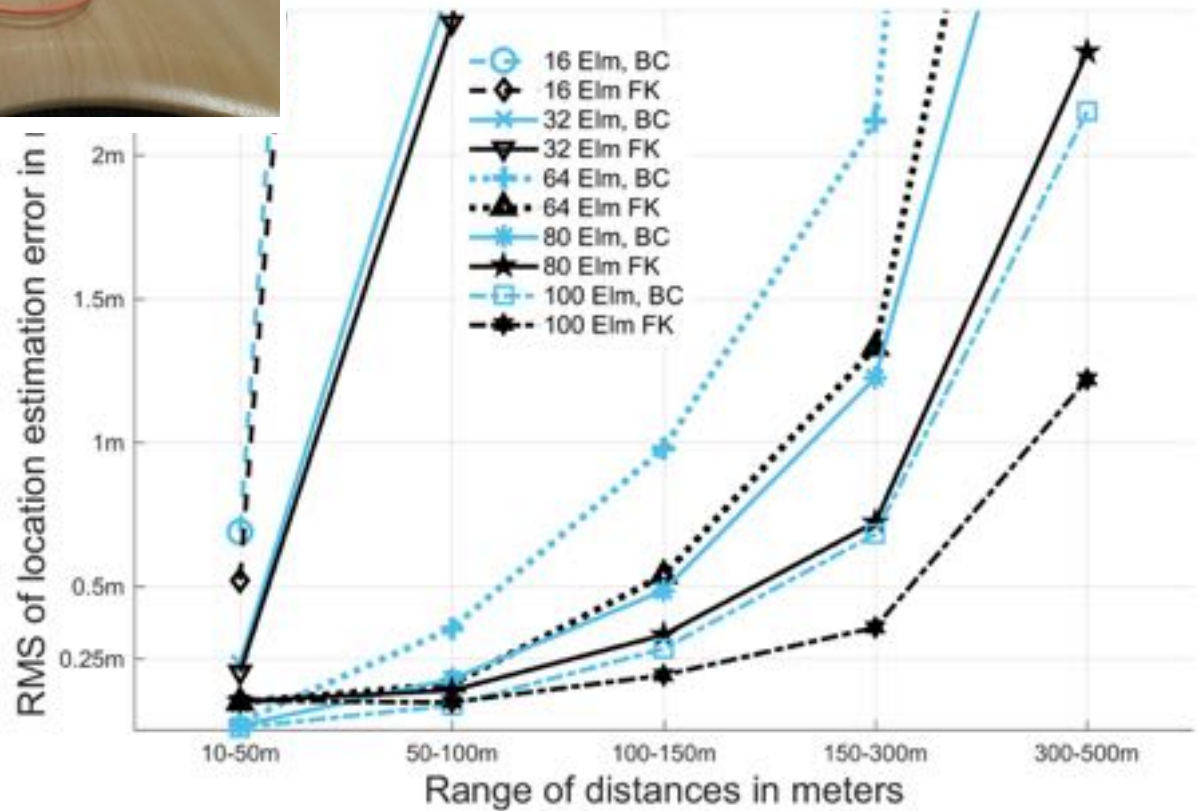
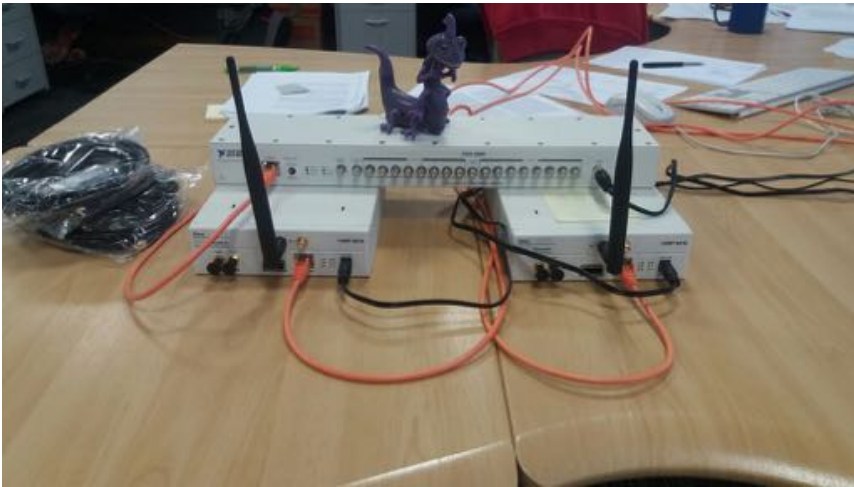
User Localization: Key idea

- Phase detection and sorting



$$\sqrt{(x - x_i)^2 + (y - y_i)^2 + (z - z_i)^2} = R + R_i$$

Results



Summary

- Datacenter networks
- Software defined networks
- Delay tolerant networks
- Wireless sensor networks
- Low power wide area networks