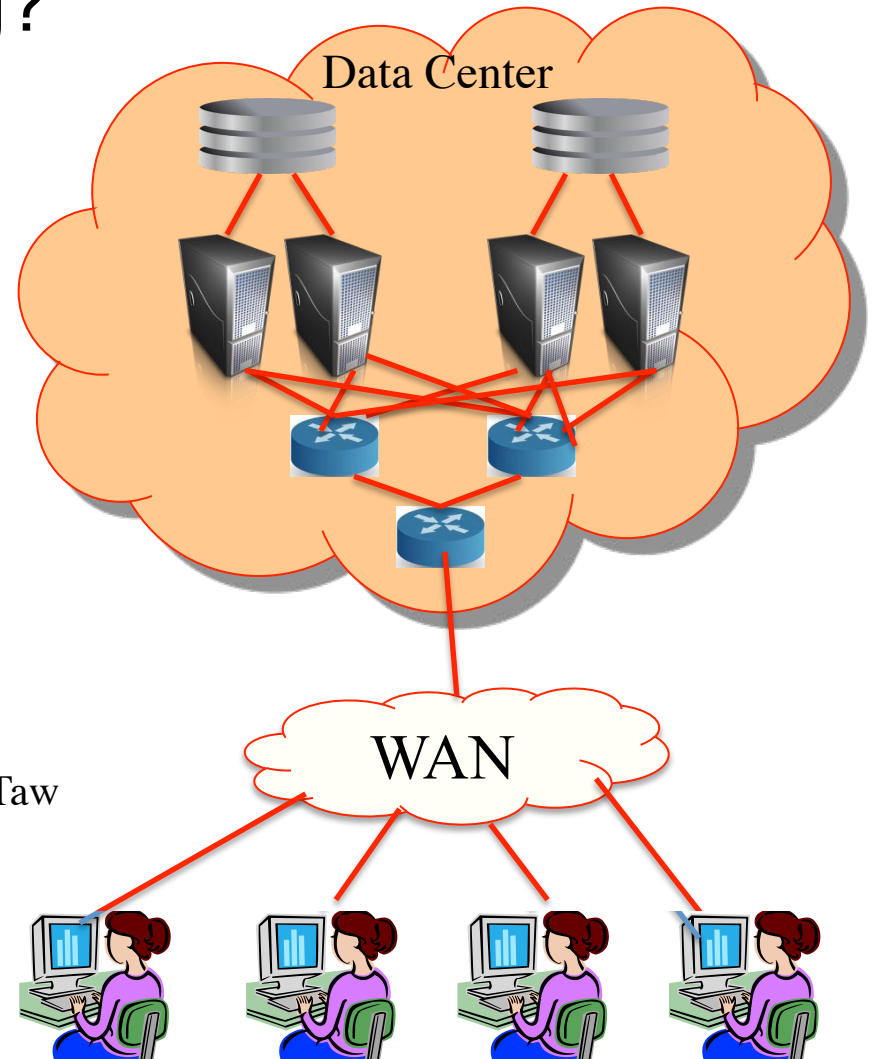# Lecture 25 Overview

- ## 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
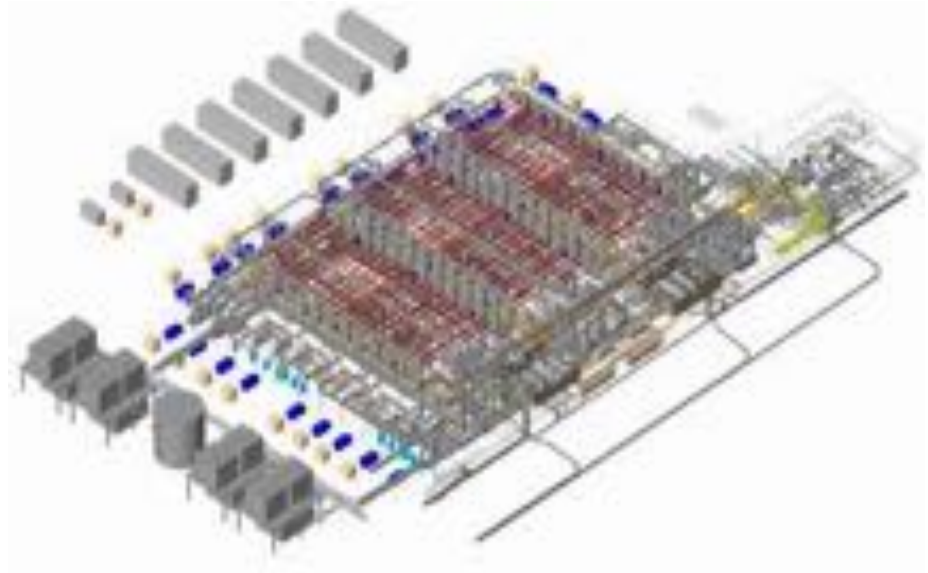

Data Center

WAN

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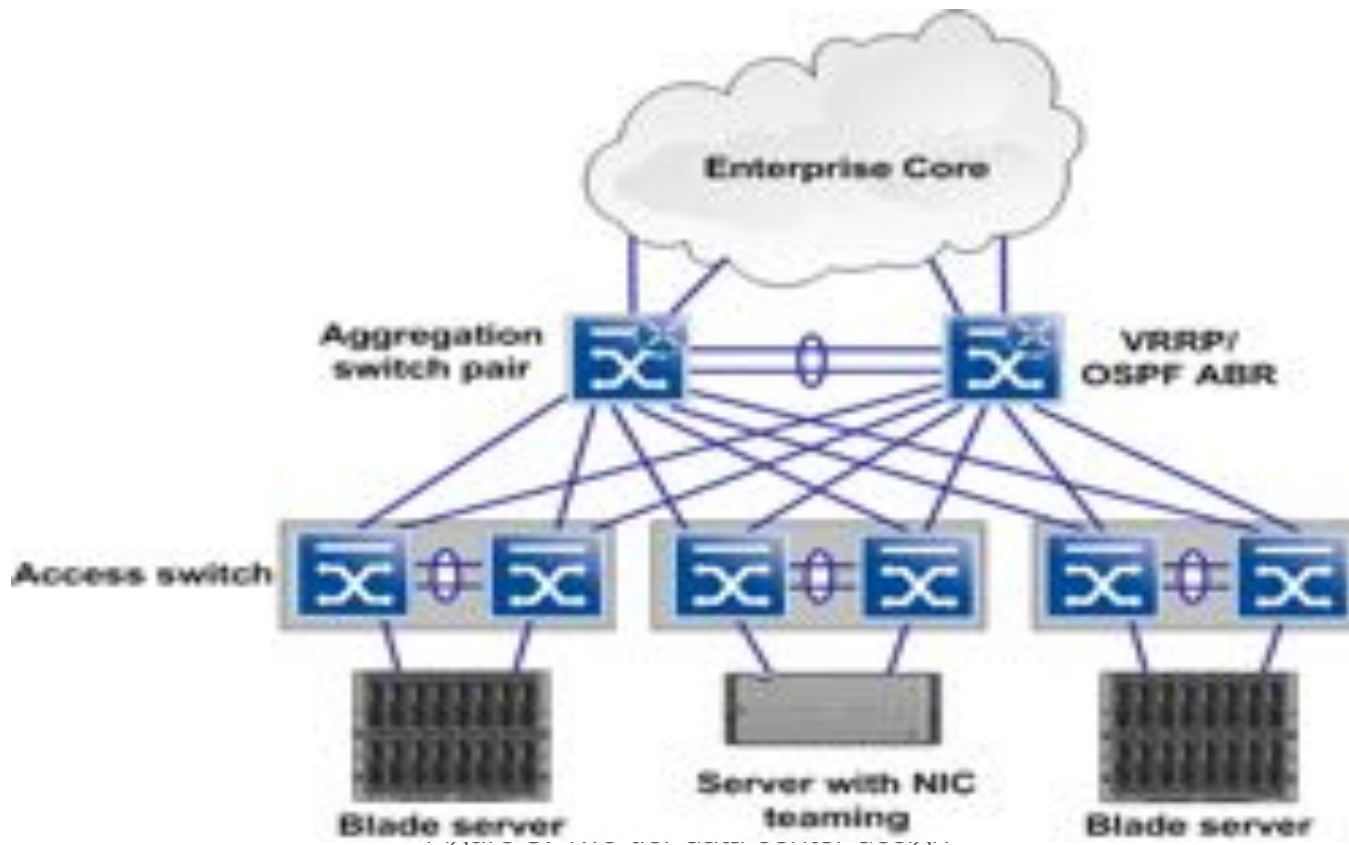40 Ports 10GE/FCoE/DCE, fixed
2 Expansion module slots

Fibre Channel
8 Ports 1/2/4G FC

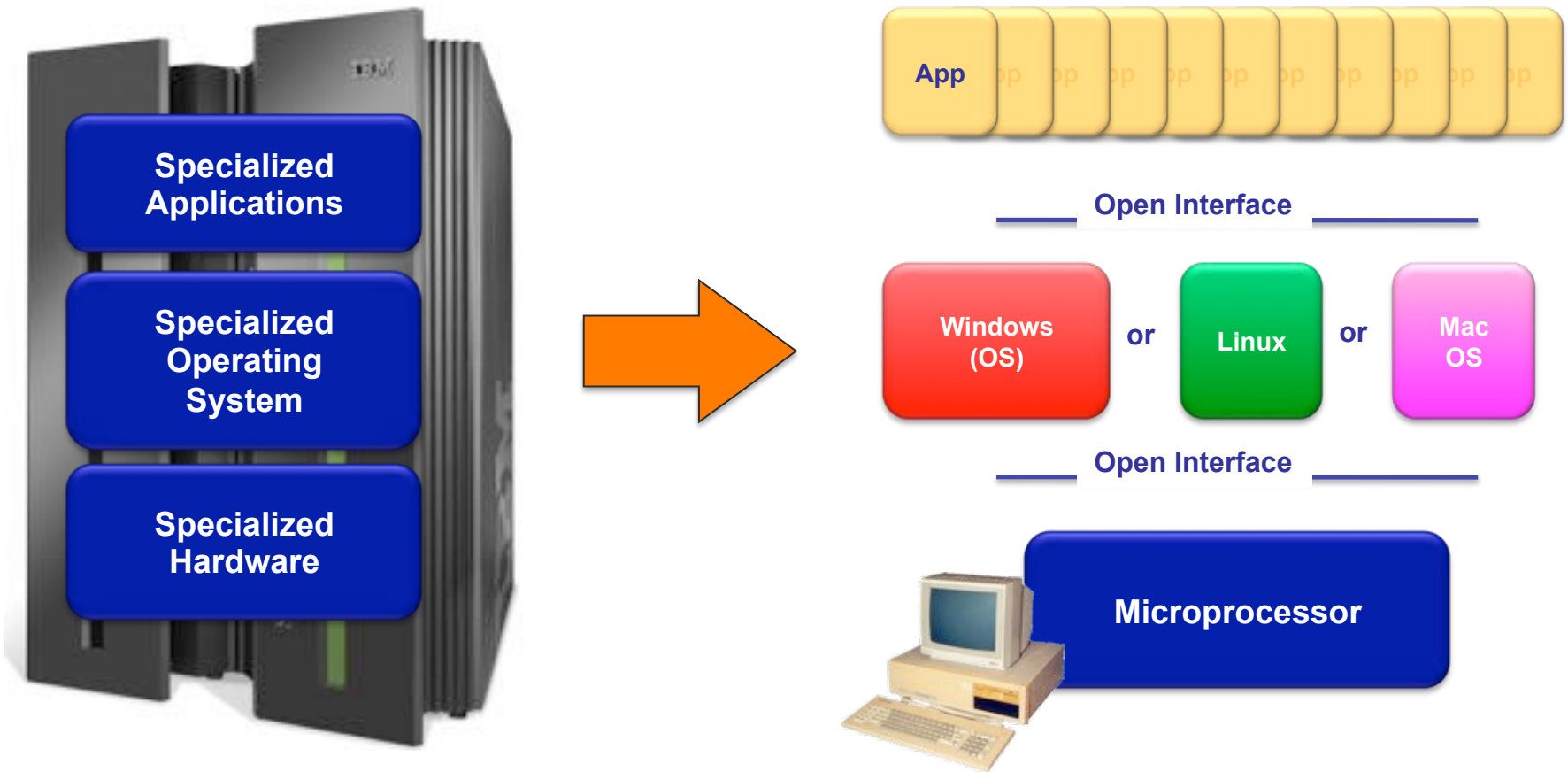# Data Center Network Design

- 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
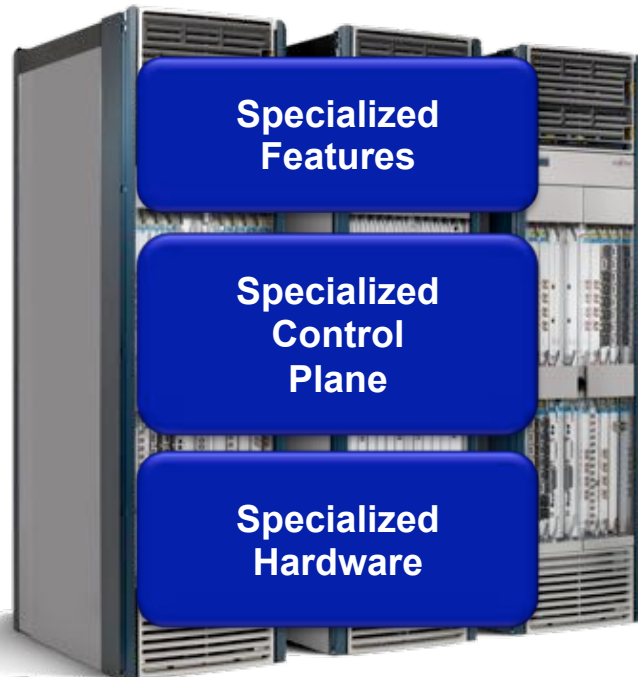
Limitations of Current Network Architecture

Specialized Applications

Specialized Operating System

Specialized Hardware

Vertical

App

Open Interface

Windows (OS) or **Linux** or **Mac OS**

Open Interface
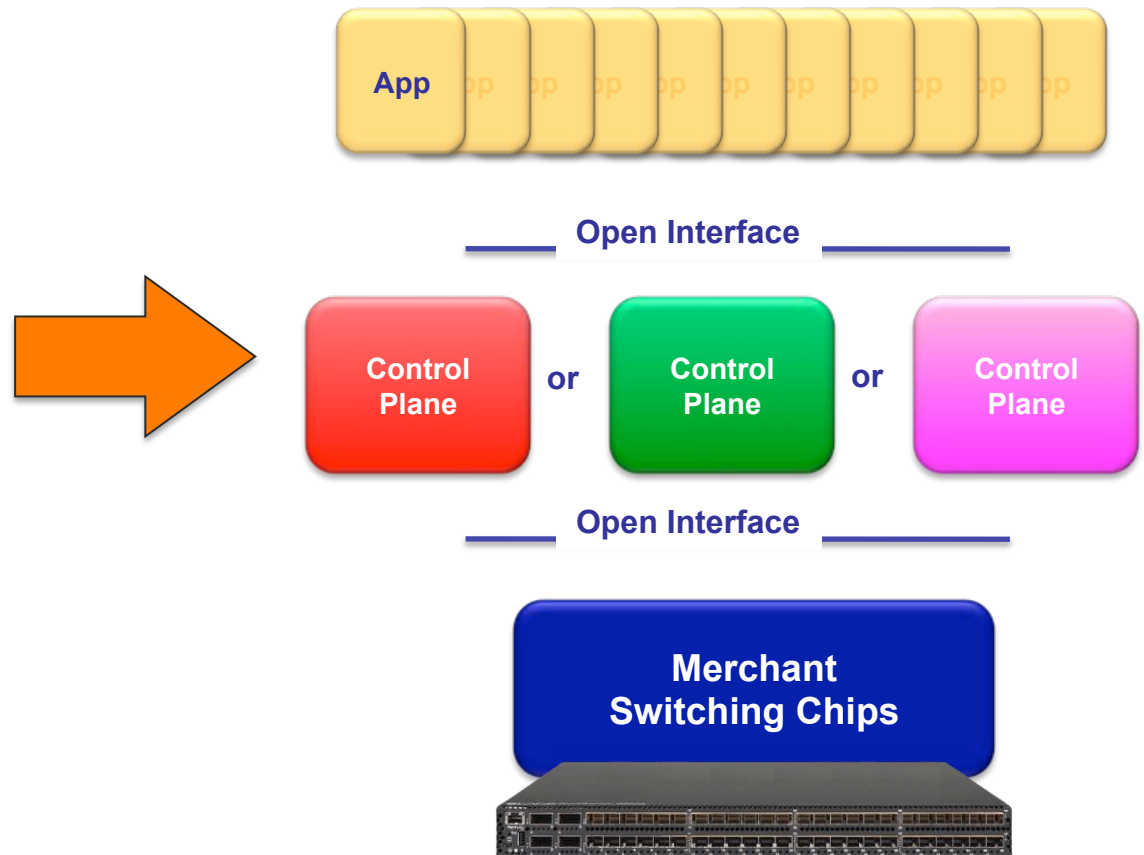
Microprocessor

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
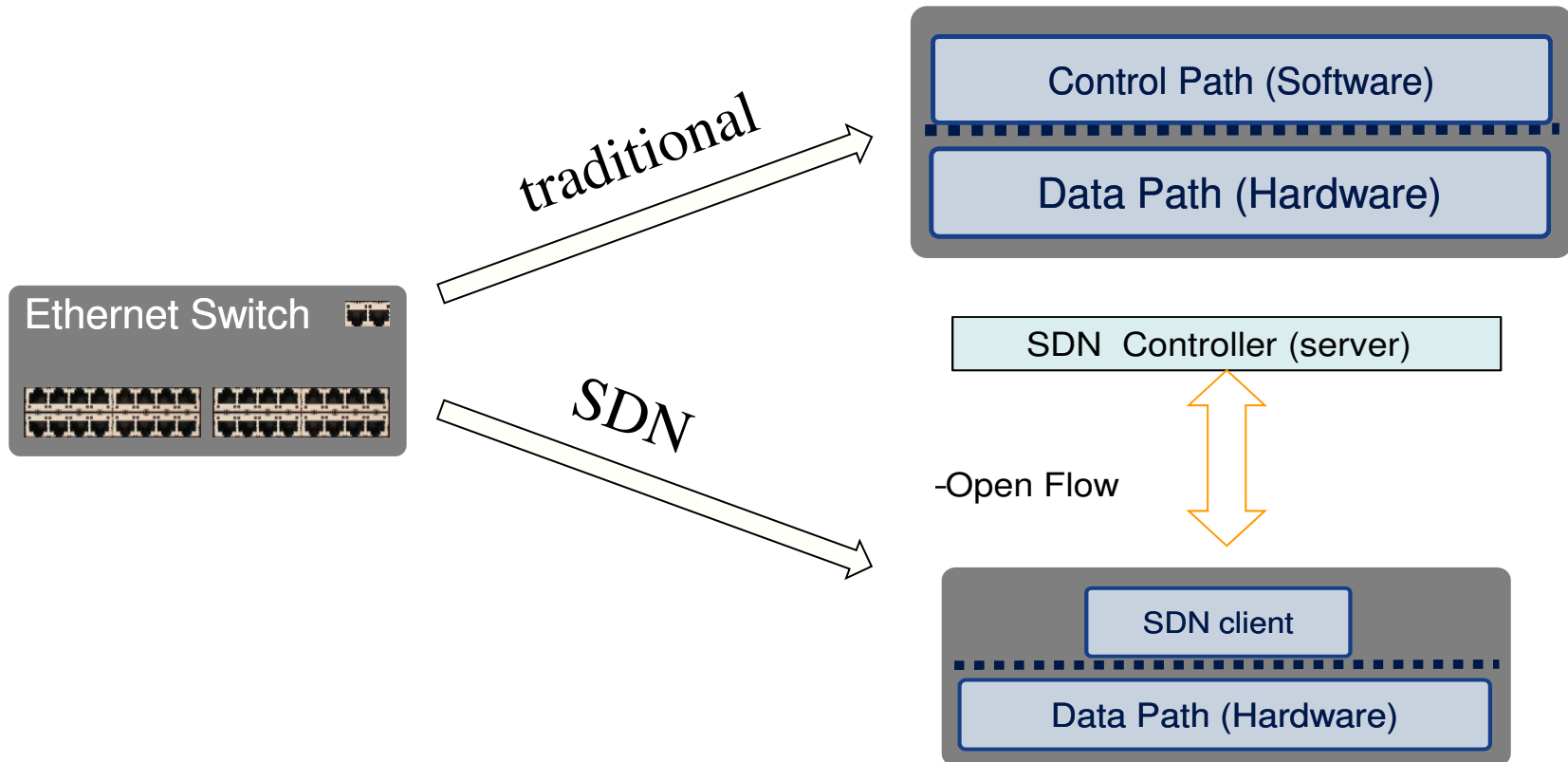
Need for New Network Architectures

Specialized Features

Specialized Control Plane

Specialized Hardware

Horizontal

App

Open Interface

Control Plane   or   Control Plane   or   Control Plane
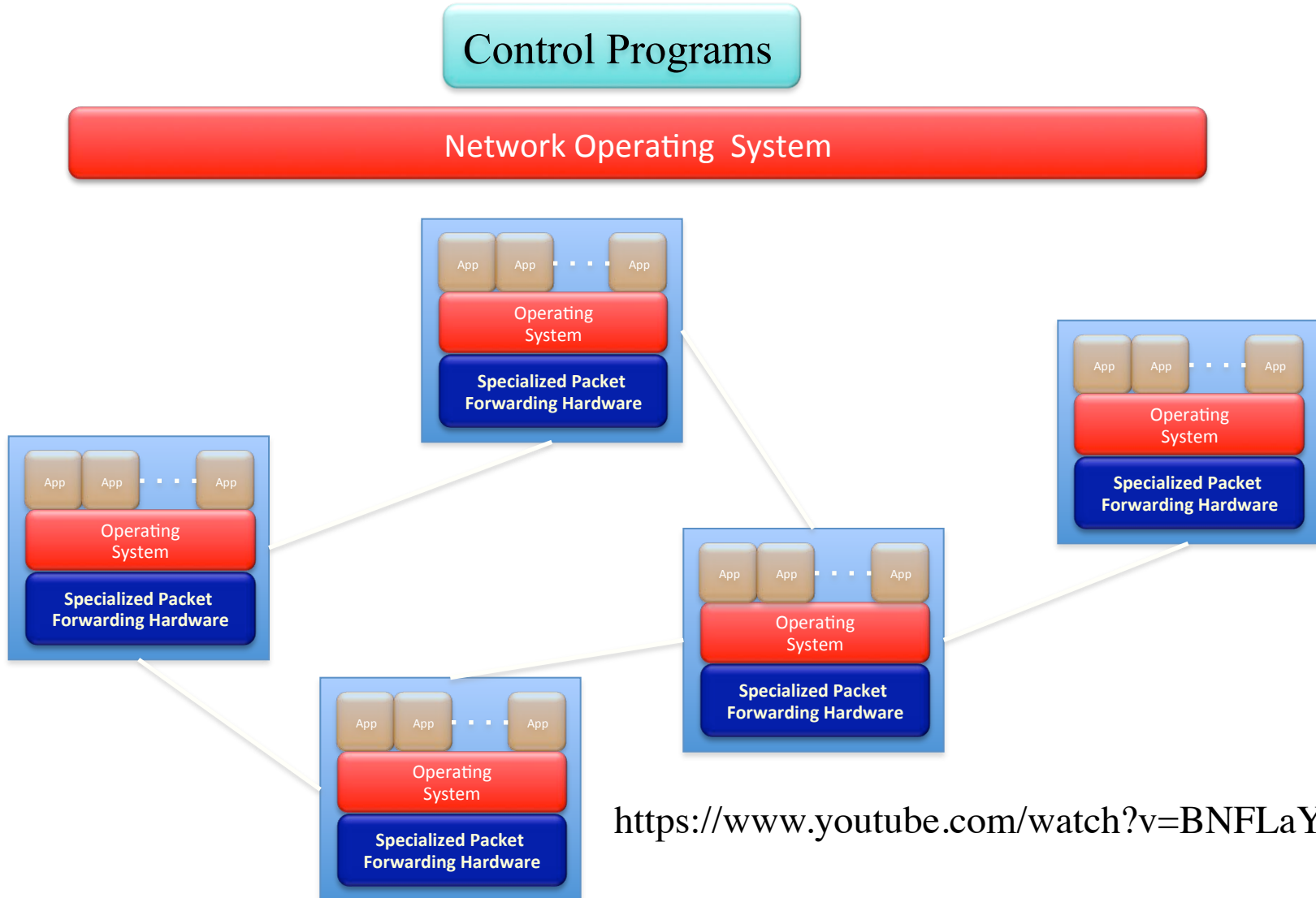
Open Interface

Merchant Switching Chips

Software Defined Networking

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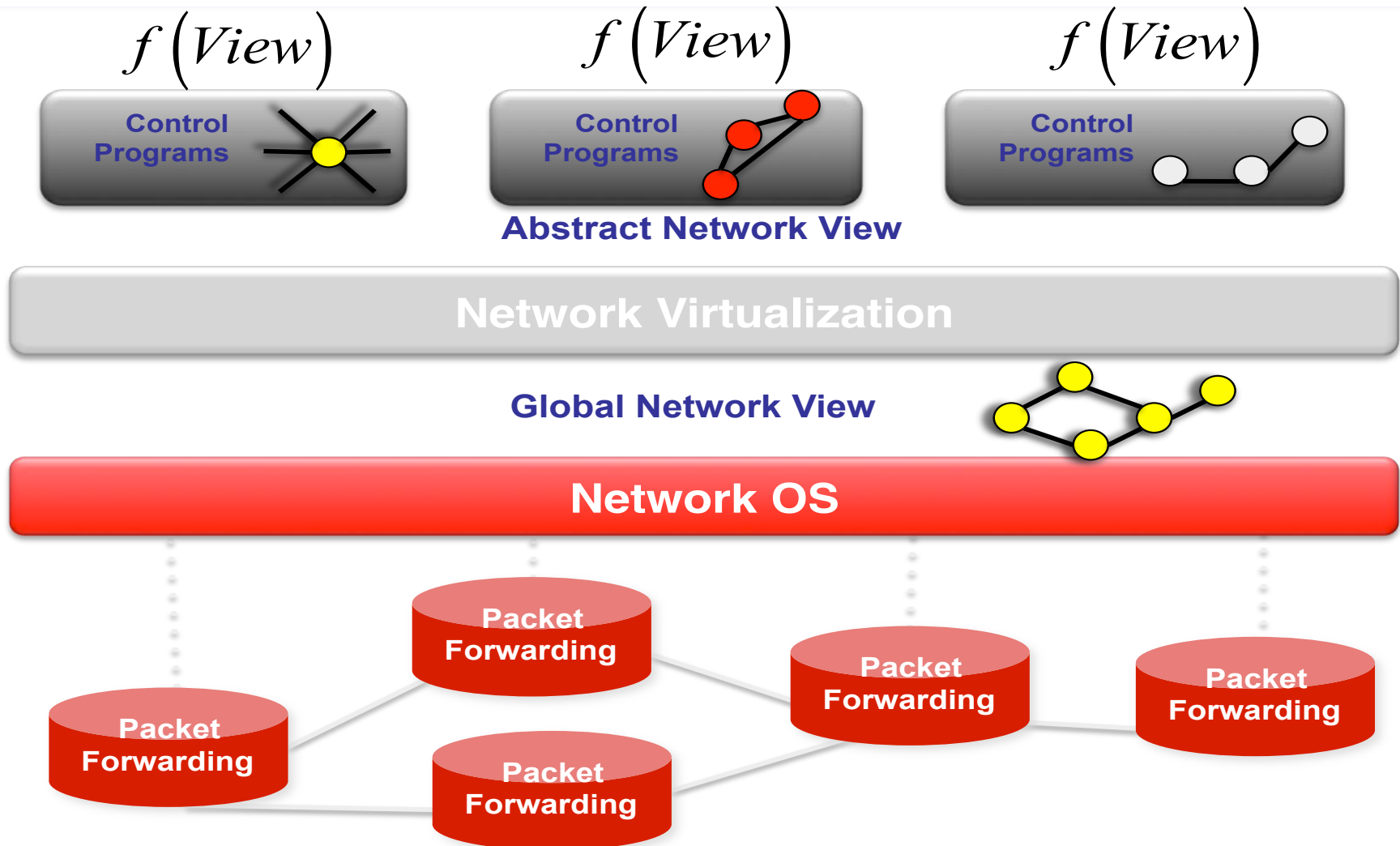
Ethernet Switch

traditional

Control Path (Software)

Data Path (Hardware)

SDN

SDN Controller (server)

-Open Flow

SDN client

Data Path (Hardware)

What is SDN? An OS for Networks

Control Programs

Network Operating System

App App ... App
Operating System
Specialized Packet Forwarding Hardware

App App ... App
Operating System
Specialized Packet Forwarding Hardware

App App ... App
Operating System
Specialized Packet Forwarding Hardware

App App ... App
Operating System
Specialized Packet Forwarding Hardware

App App ... App
Operating System
Specialized Packet Forwarding Hardware

https://www.youtube.com/watch?v=BNFLaY3YhxY

Software Defined Networking

$$f\left(View\right)$$

$$f\left(View\right)$$

$$f\left(View\right)$$

Control Programs

Control Programs

Control Programs

Abstract Network View

Network Virtualization

Global Network View

Network OS

Packet Forwarding

Packet Forwarding

Packet Forwarding

Packet Forwarding

Packet Forwarding

OpenFlow

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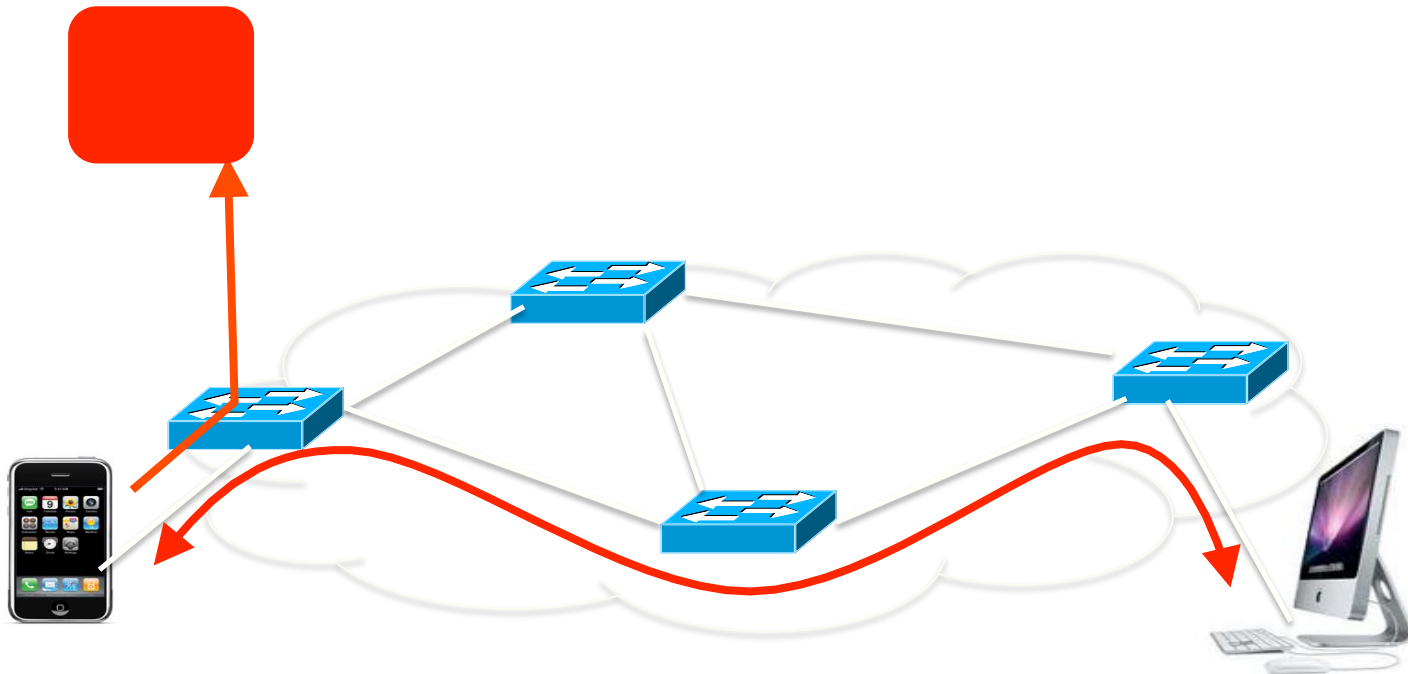
Challenged Networks

- Networks may operate poorly in environments characterized by very long delay paths and frequent network partitions.
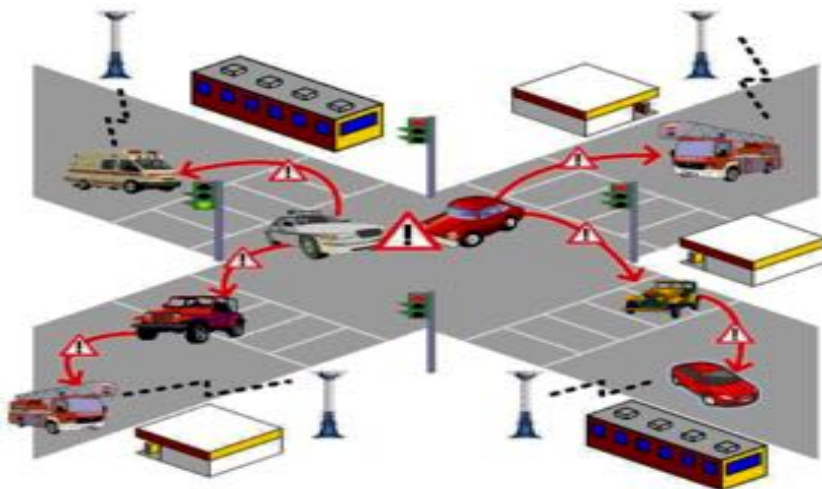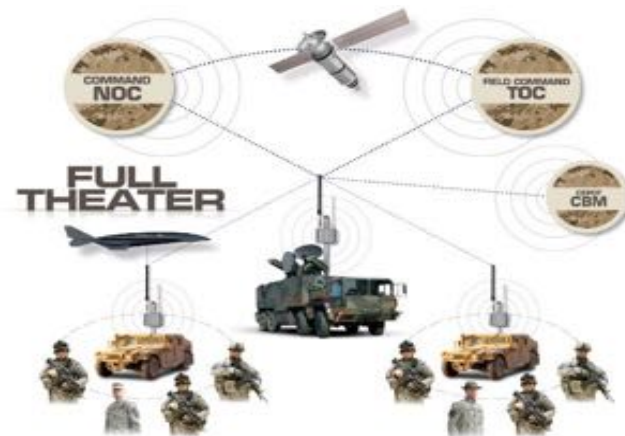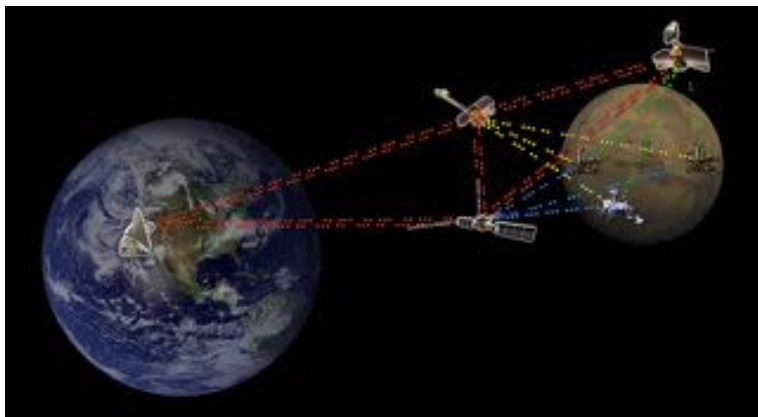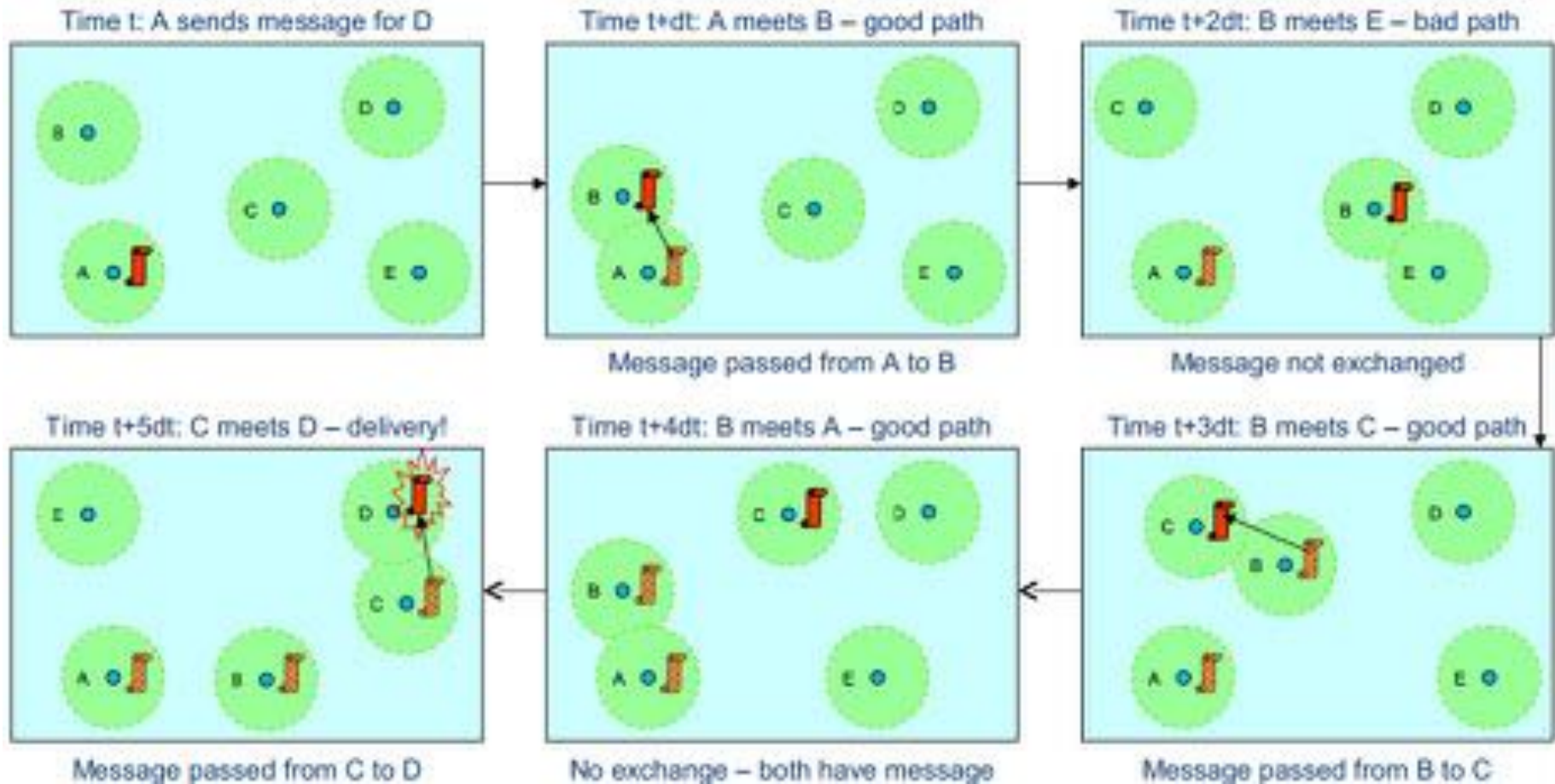
Delay-tolerant Networking (DTN)

- 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

Time t: A sends message for D

Time t+dt: A meets B – good path
Message passed from A to B

Time t+2dt: B meets E – bad path
Message not exchanged

Time t+5dt: C meets D – delivery!
Message passed from C to D

Time t+4dt: B meets A – good path
No exchange – both have message

Time t+3dt: B meets C – good path
Message passed from B to C

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

Internet

2

City

bike

1

Village
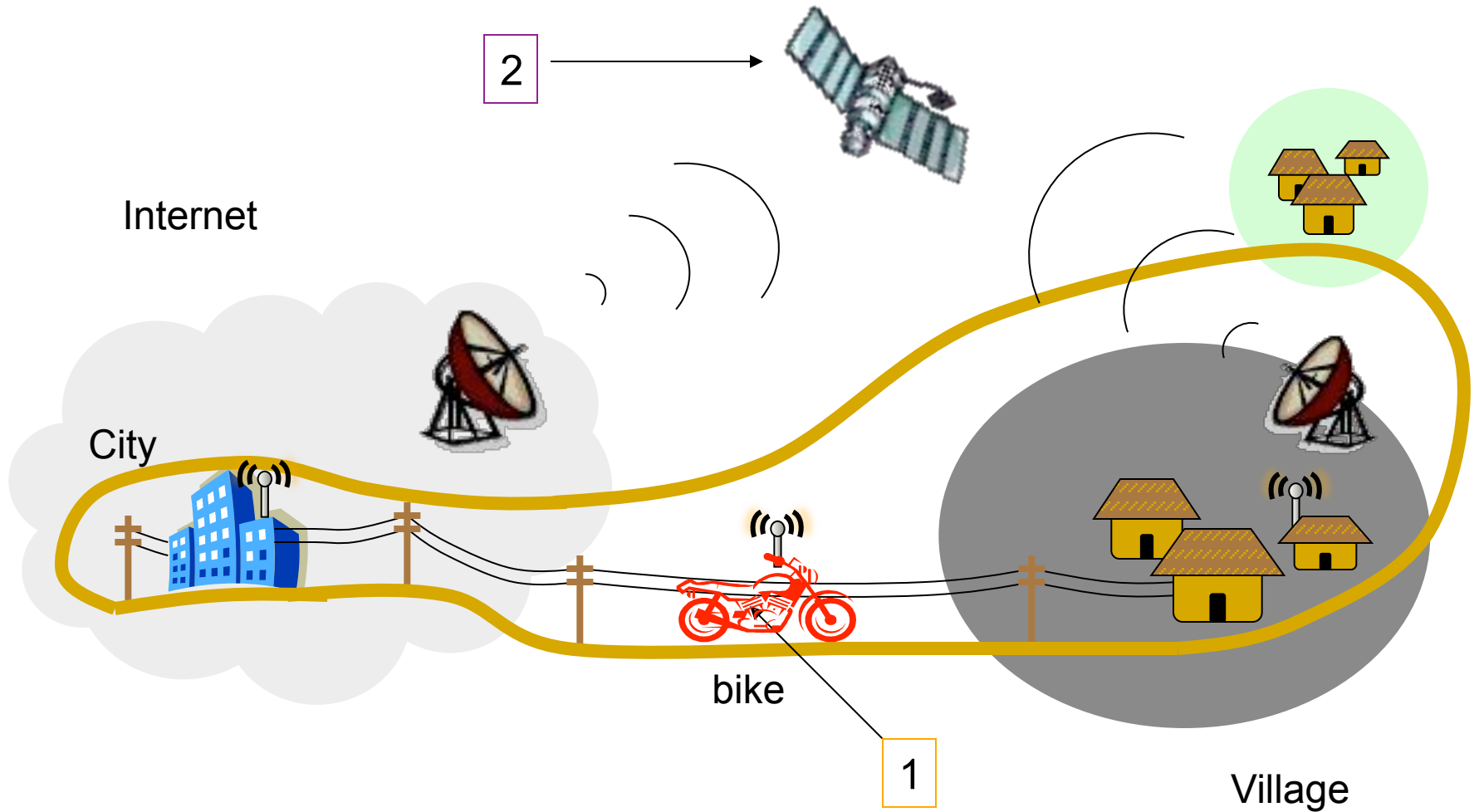
Google's Balloon Network

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."
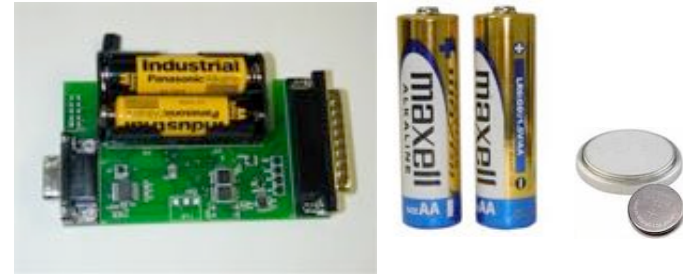
National Research Council

Hardware

WeC 99
"Smart Rock"

Rene 11/00

Mica 1/02

Telos 4/04
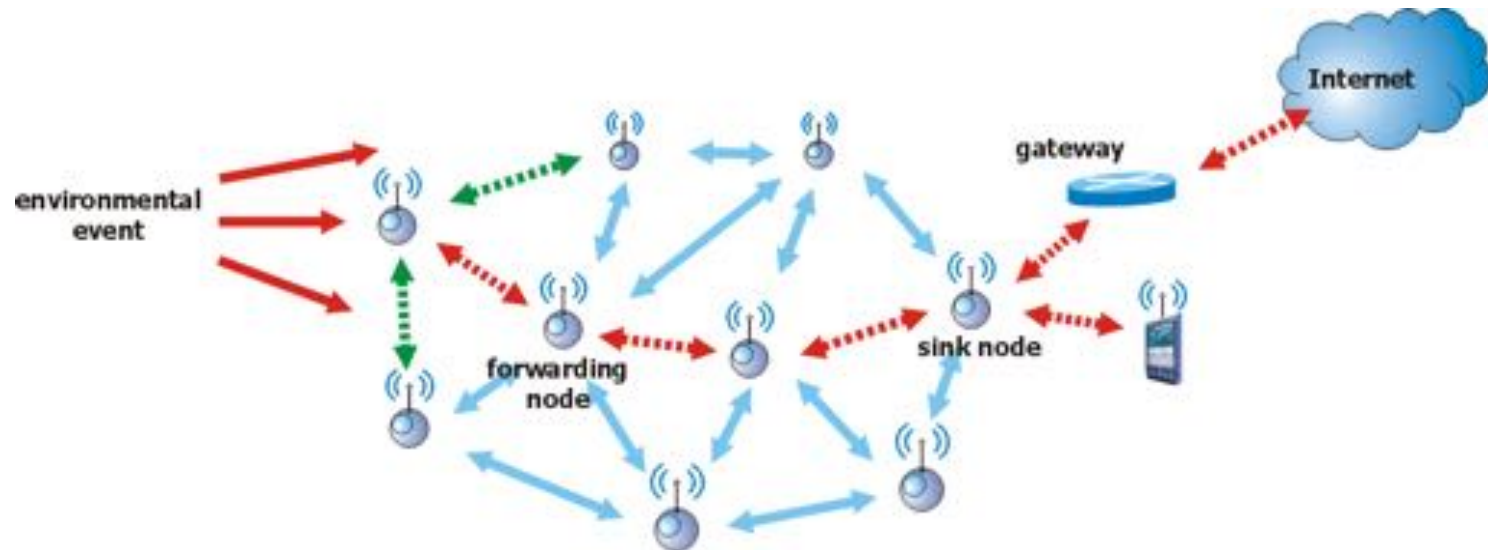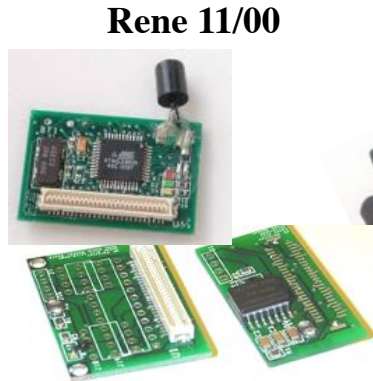
Spec 6/03
"Mote on a chip"
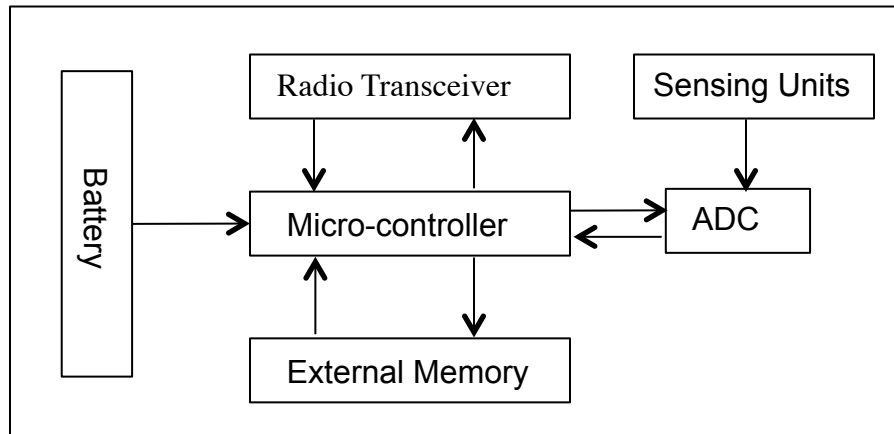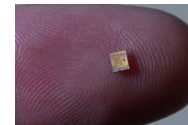
Sensor Node Architecture

Sensing Unit:
- ❑ Temperature
- ❑ Humidity
- ❑ Light
- ❑ Pressure
- ❑ Image
- ❑ 3D coordinates
- ❑ …

Features & Challenges

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

Mote Type Year	WeC 1999	Rene 1999	Rene 2 2000	Dot 2000	Mica 2001	Mica2Dot 2002	Mica 2 2002	Telos 2004
Microcontroller								
Type	AT90LS8535	ATmega163			ATmega128			TI MSP430
Program memory (KB)	8	16			128			60
RAM (KB)	0.5	1			4			2
Active Power (mW)	15	15			8	33		3
Sleep Power (μW)	45	45			75	75		6
Wakeup Time (μs)	1000	36			180	180		6
Nonvolatile storage								
Chip	24LC256				AT45DB041B			ST M24M01S
Connection type	I²C				SPI			I²C
Size (KB)	32				512			128
Communication								
Radio	TR1000			TR1000		CC1000		CC2420
Data rate (kbps)	10			40		38.4		250

Applications(cont.)

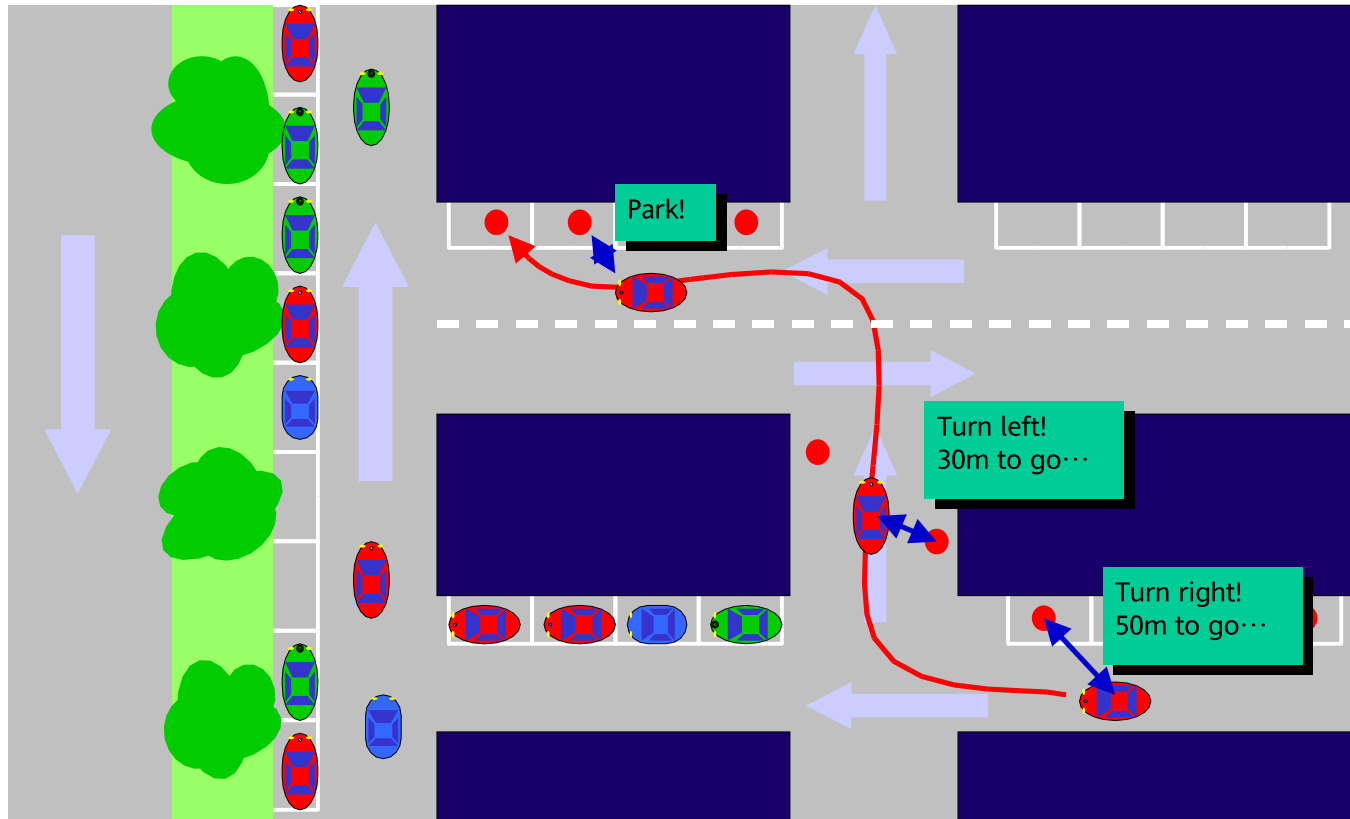**Smart House**

Applications(cont.)

Traffic Control

& Inteligent 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

Internet of Things

Source: http://blog.trentonsystems.com/internet-of-things-crosses-business-personal-boundaries/

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)
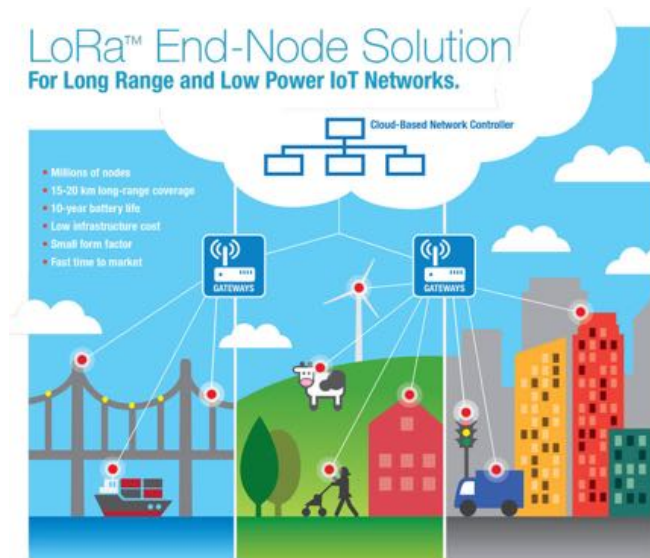
Architecture
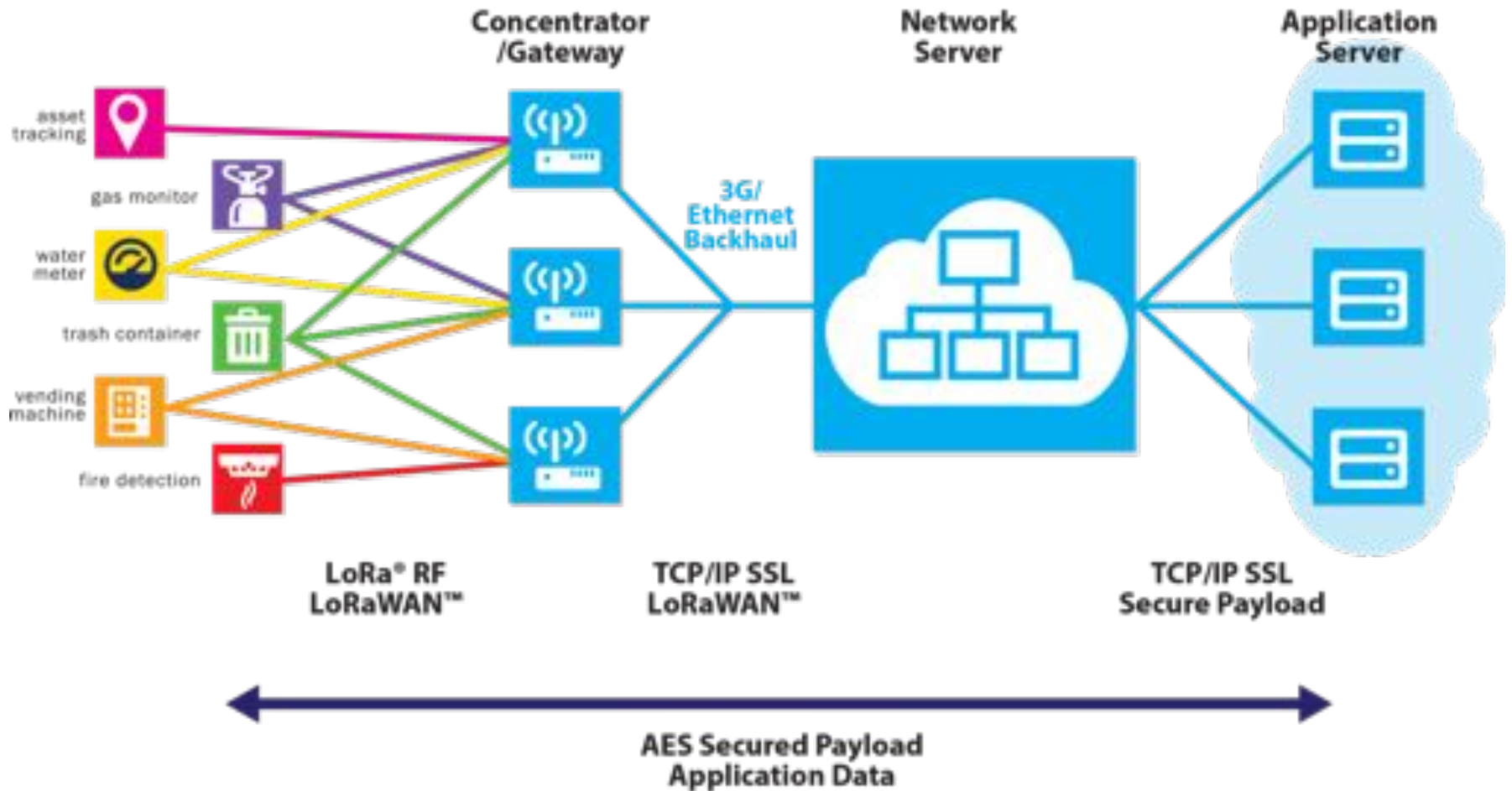
LoRa Technology

- 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.
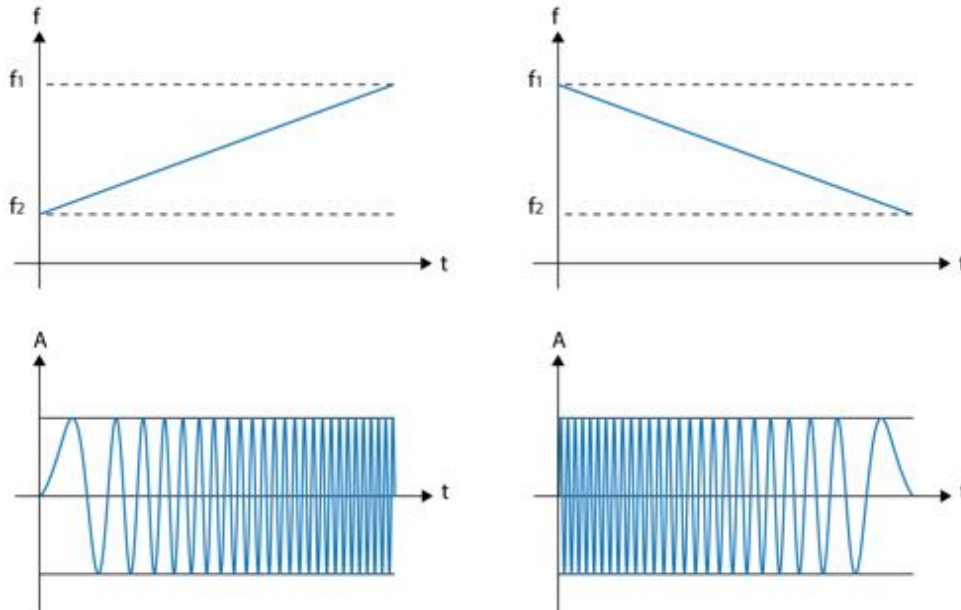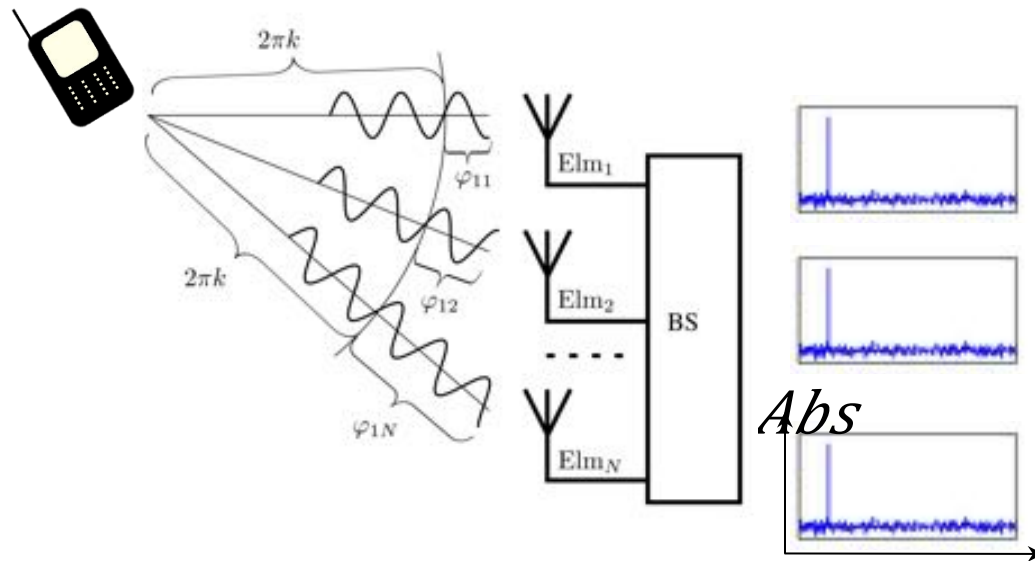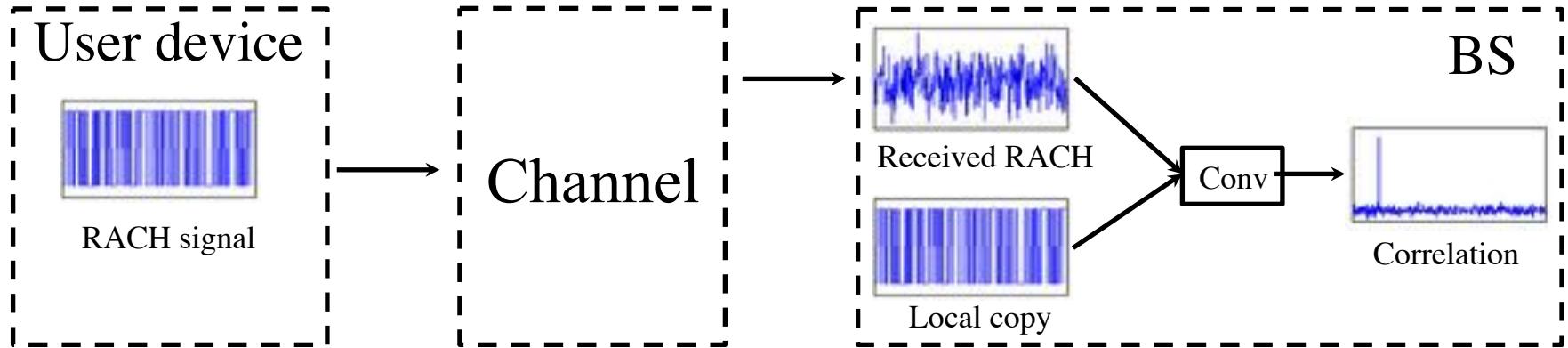
User Localization using Massive MIMO

- Difference between plain wave propagation (PWP) and spherical wave propagation (SWP)
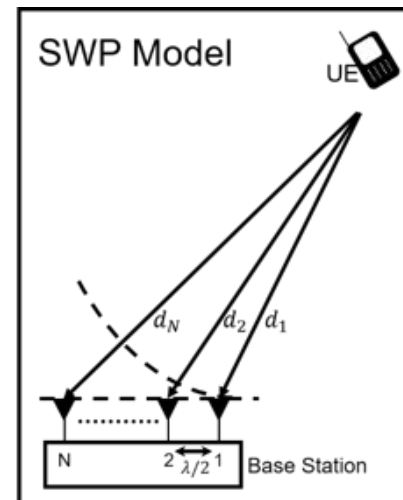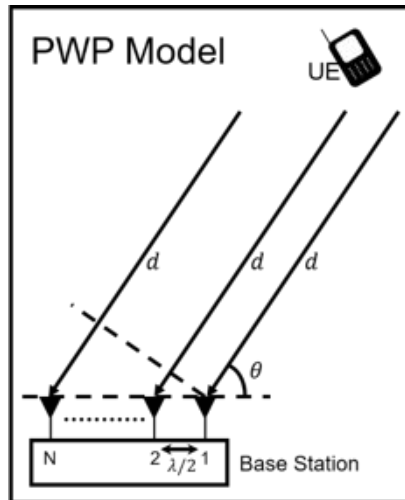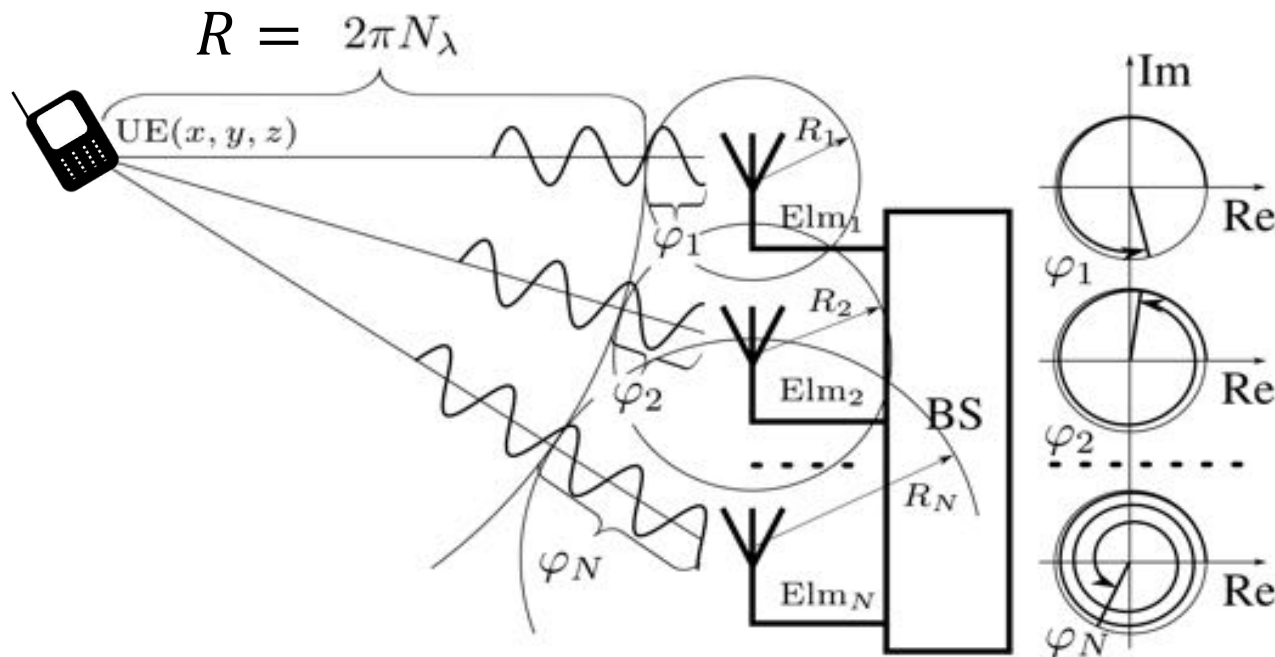
User Localization: Key idea

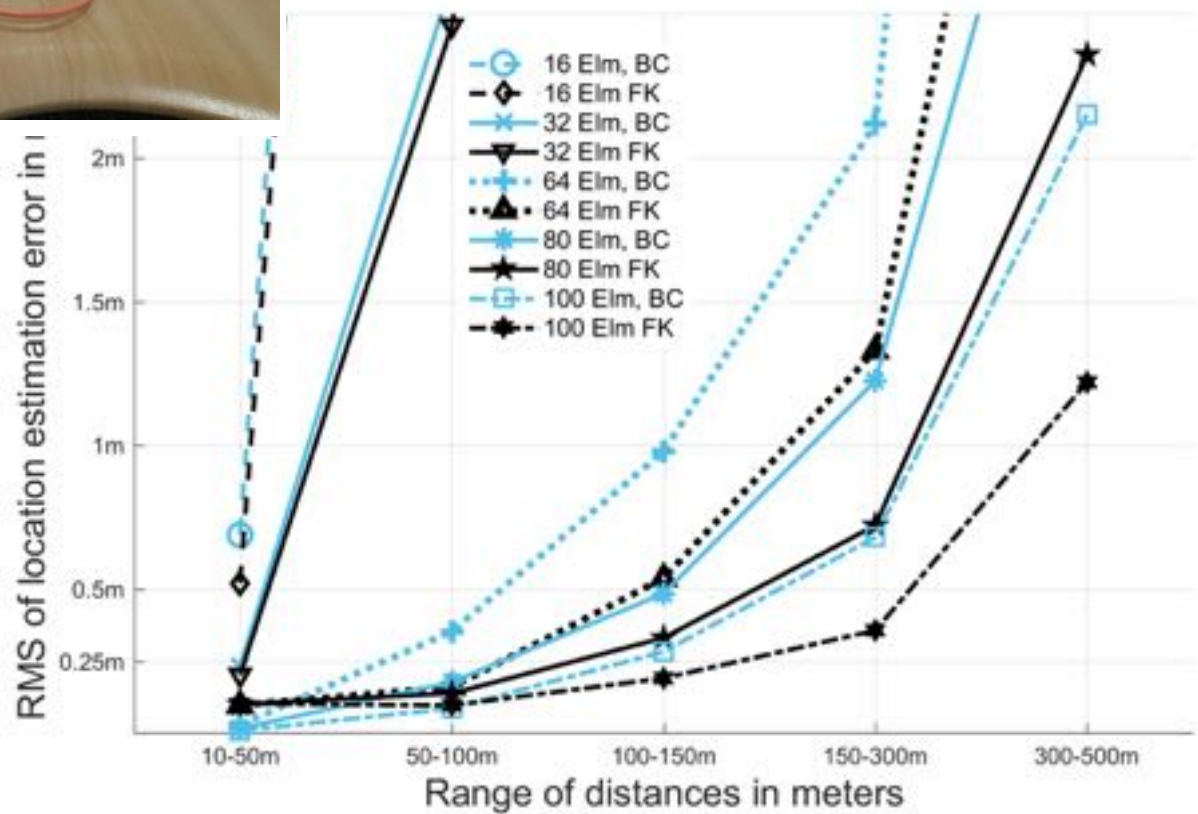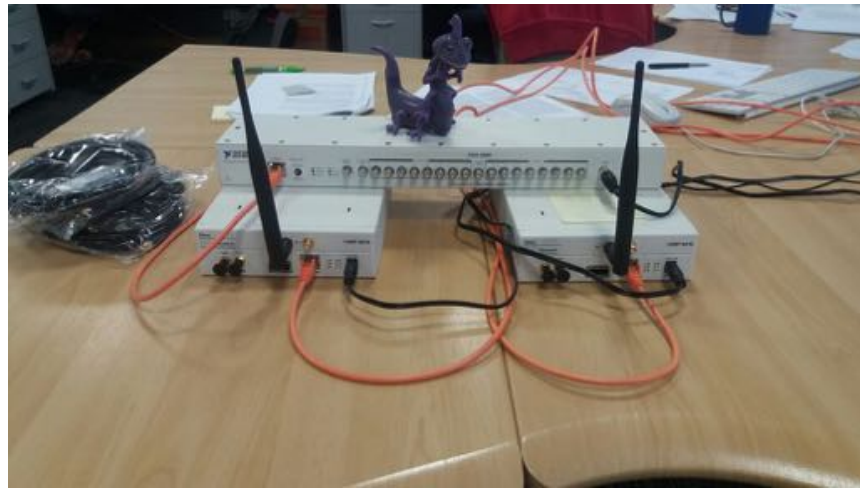- Random Access Channel (RACH) synchronization

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