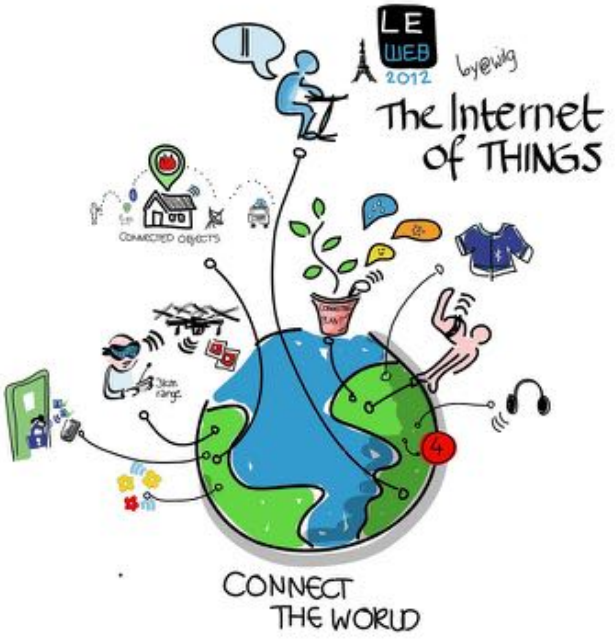
Lecture Overview

- Last Lecture
  - LiFi and NoCs
- This Lecture
  - IoT (RFID/Big Data), Software-defined Networks (SDN)
  - Source: lecture note
- Next Lecture
  - Presentation

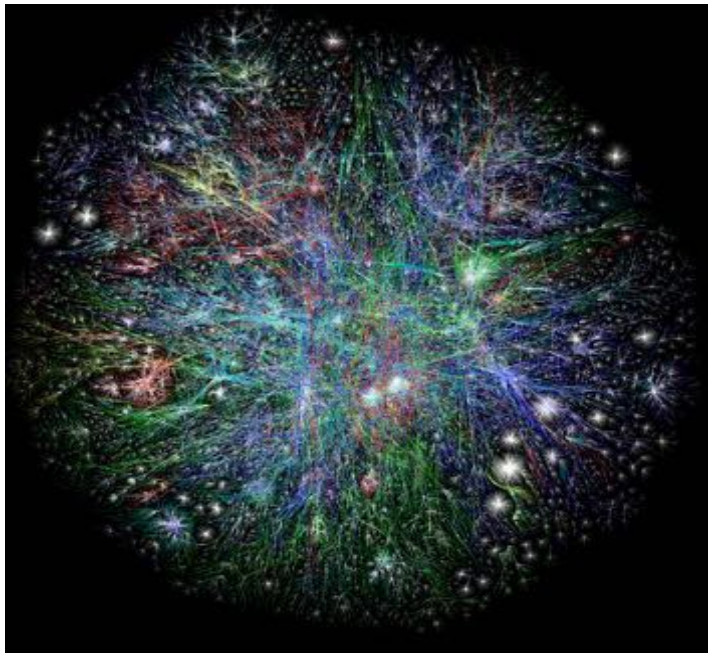
Outline

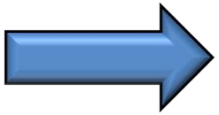
- This Lecture
  - Internet of Things
    - RFID
    - Big Data
  - Software-defined Networks (SDN)



What is IoT?

Starting from the Internet





- Internet appears everywhere in the world
- but it is still a connection between people and people

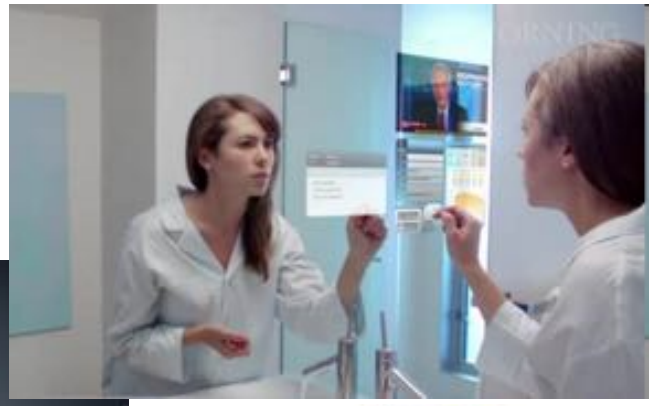
What is IoT?

- Internet connects all people, so it is called “the Internet of People”

- IoT connects all things, so it is called “the Internet of Things”

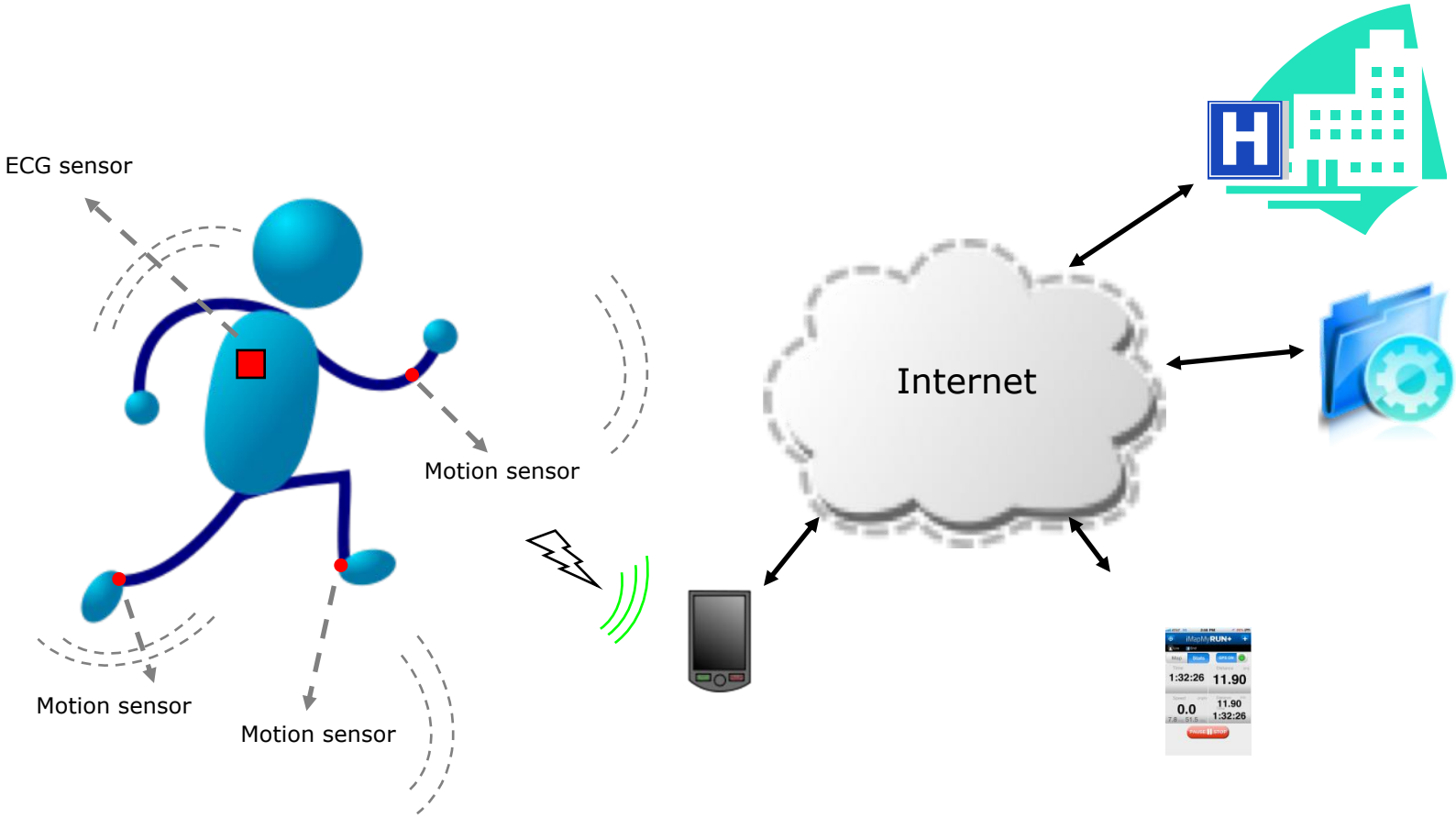
What is IoT?

More “Things” are being connected
Home/daily-life devices
Business and
Public infrastructure
Health-care
…



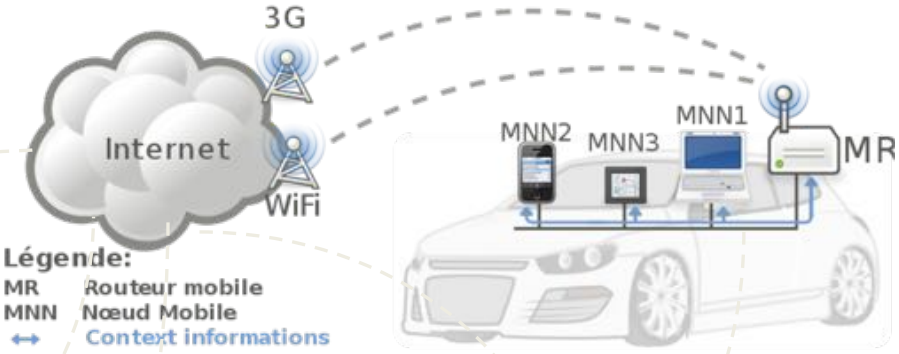
What is IoT?

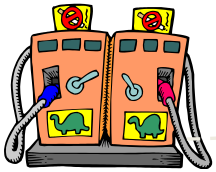
People Connecting to Things



What is IoT?

Things Connecting to Things



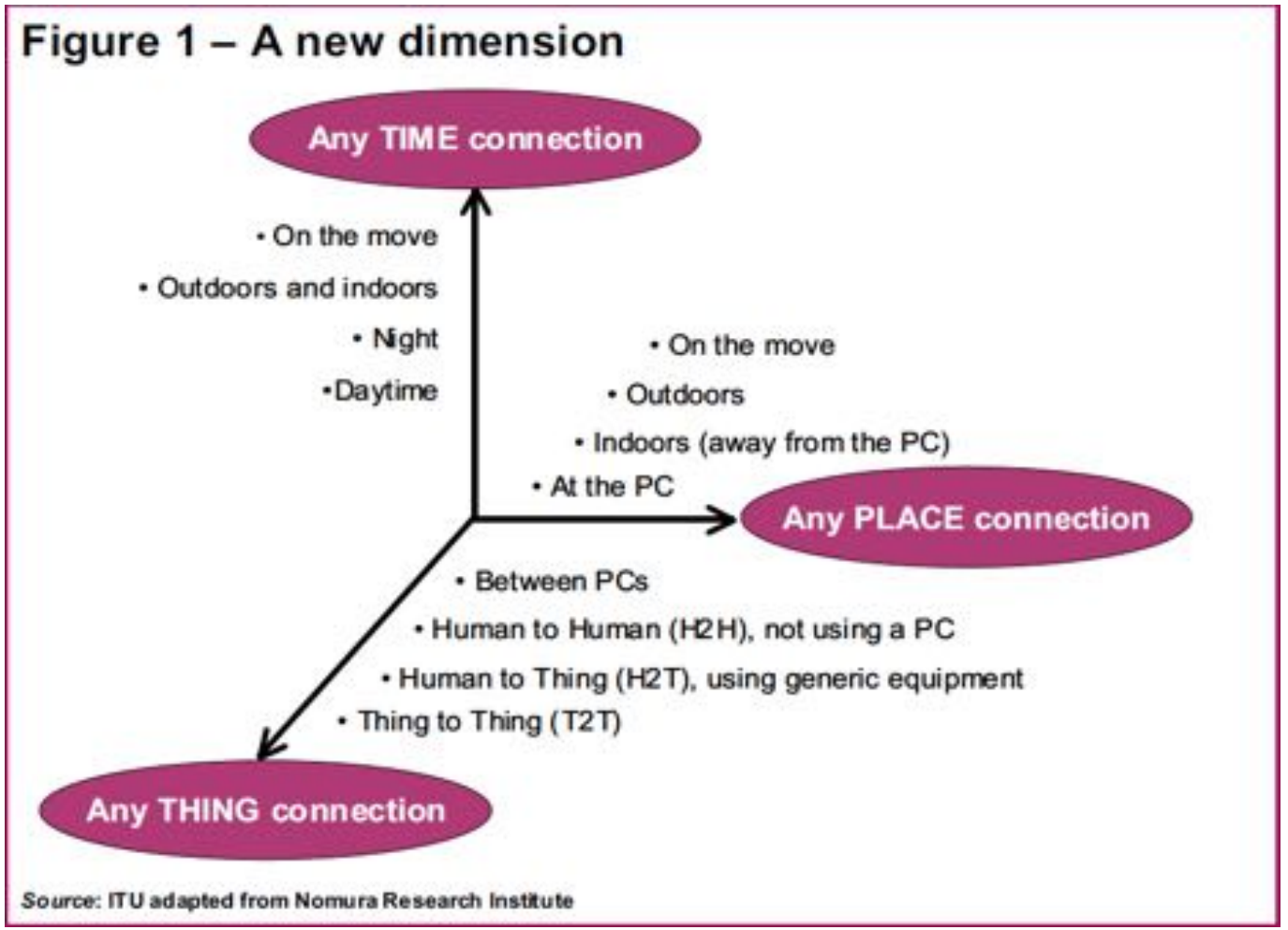


- Complex and heterogeneous resources and networks

What is IoT?

More nodes, more connections, Any TIME, Any PLACE + Any THING

From any time, any place connectivity for anyone, we will now have connectivity for anything!



What is IoT?

https://www.youtube.com/watch?v=c-Ekz2kK7J4

- What's the Internet of Things

(1) The Internet of Things, also called The Internet of Objects, refers to a wireless network between objects, usually the network will be wireless and self-configuring, such as household appliances.

------Wikipedia

(2) By embedding short-range mobile transceivers into a wide array of additional gadgets and everyday items, enabling new forms of communication between people and things, and between things themselves.

------WSIS 2005

What is IoT?

- What's the Internet of Things

  (3) The term "Internet of Things" has come to describe a number of technologies and research disciplines that enable the Internet to reach out into the real world of physical objects.

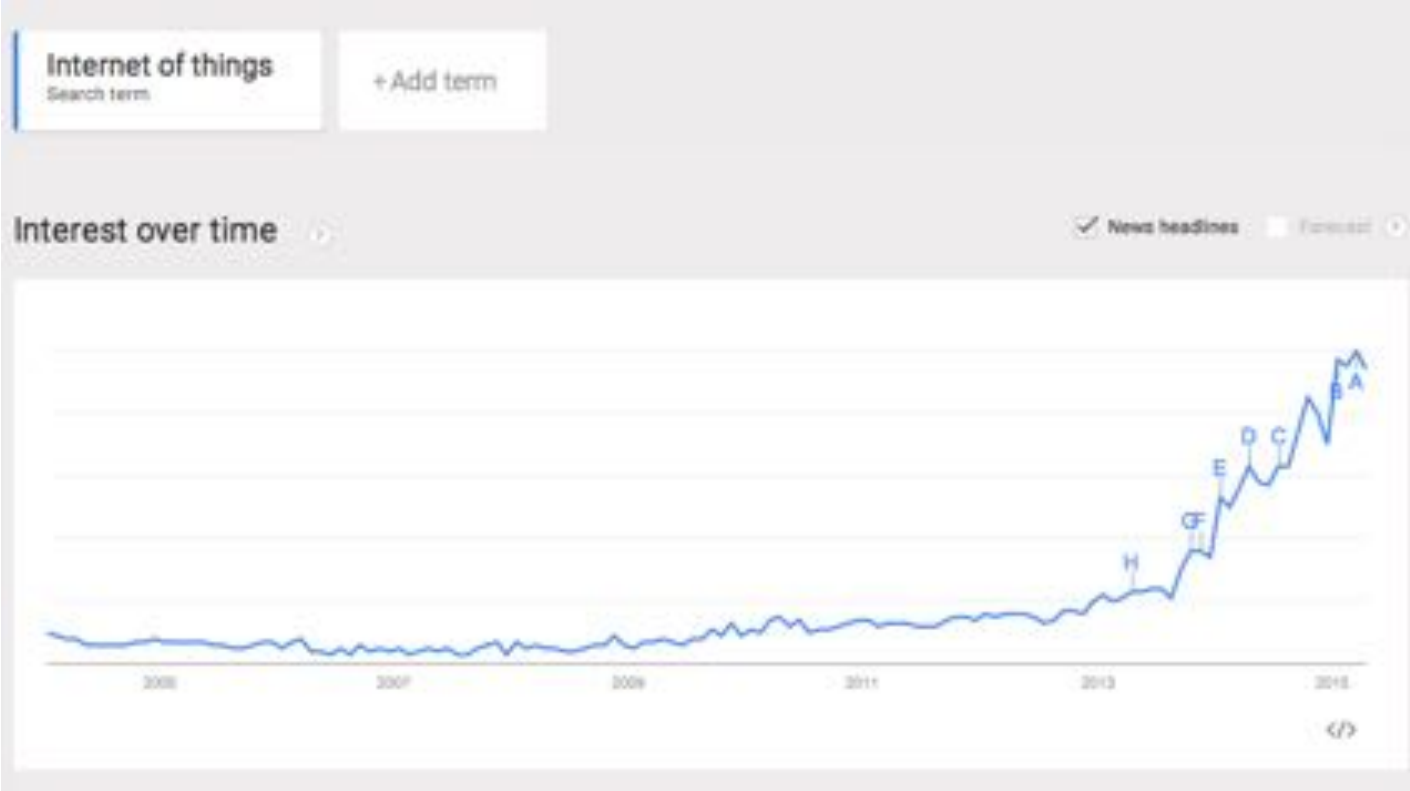
  ------IoT 2008

  (4) "Things having identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental, and user contexts".

  -------IoT in 2020

What is IoT?

- Internet of things Google trends:
  - ✓ Increasing recently, very hot topic
  - ✓ Forecast: increasing



Outline

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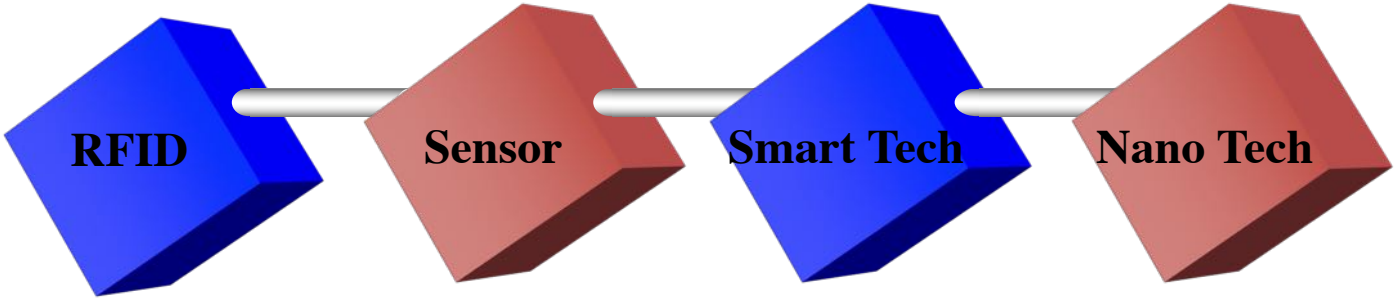
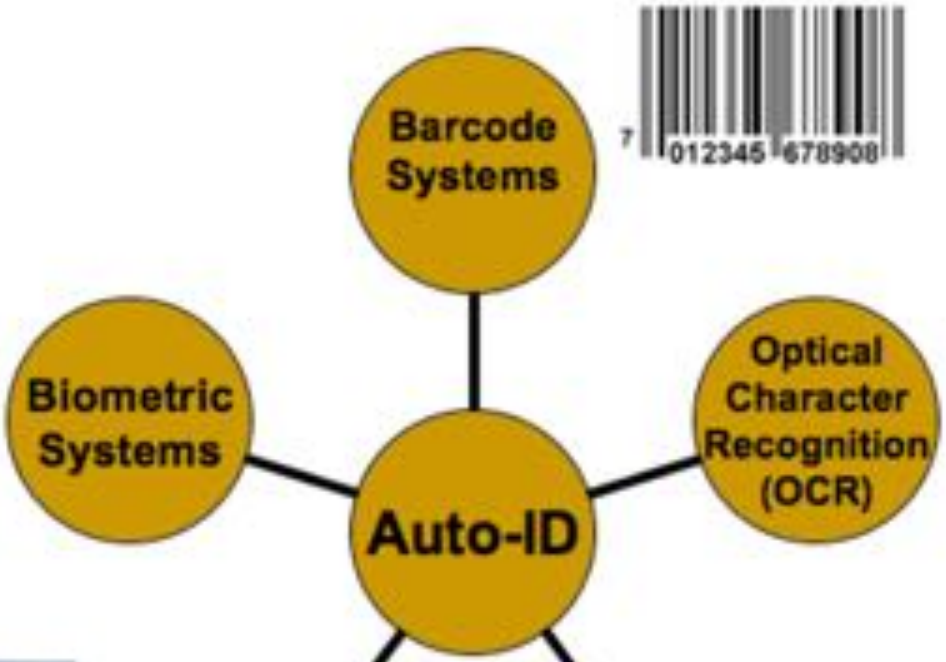
  - Internet of Things
    - RFID
    - Big Data
  - Software-defined Networks (SDN)

IoT Enabling Technologies



To identify and track the data of things	**To collect and process the data to detect the changes in the physical status of things**	**To enhance the power of the network by devolving processing capabilities to different part of the network.**	**To make the smaller and smaller things have the ability to connect and interact.**

IoT Enabling Technologies



IoT Enabling Technologies: RFID

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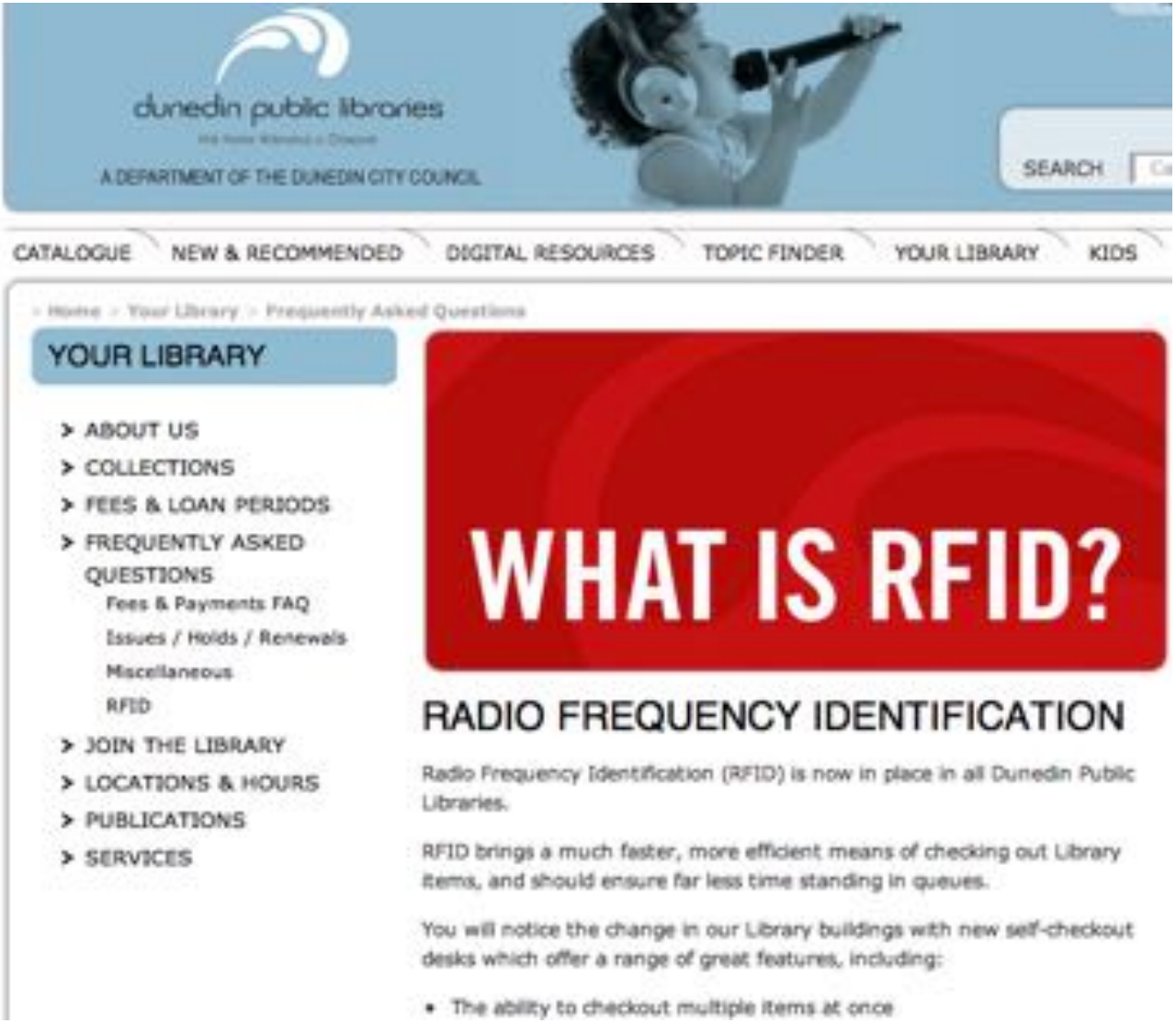
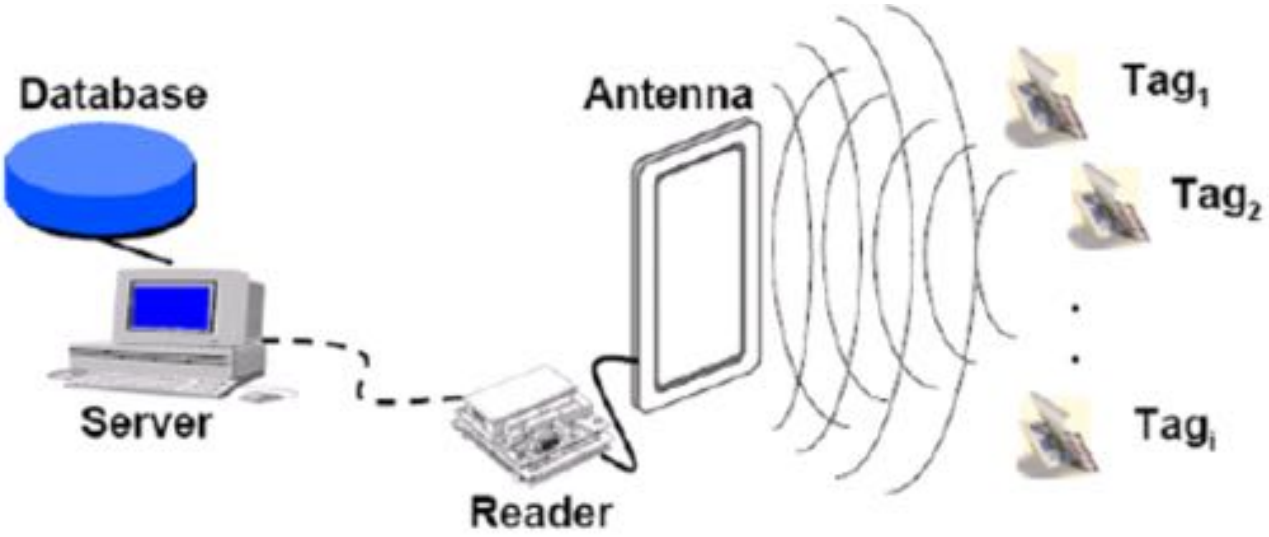


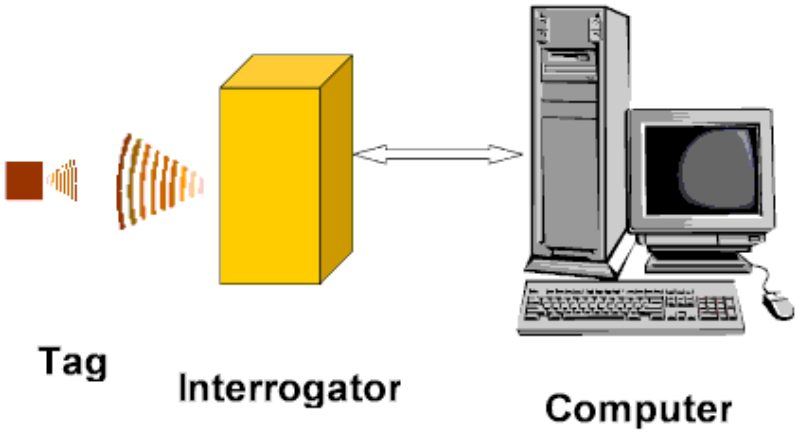
IoT Enabling Technologies: RFID

- What is RFID?
  - RFID (Radio Frequency Identification) is a technology used for electronic and wireless identification of objects, humans and animals
  - A technology that employs a microchip (smart tag) with an antenna that broadcasts its unique identifier and location to receivers.



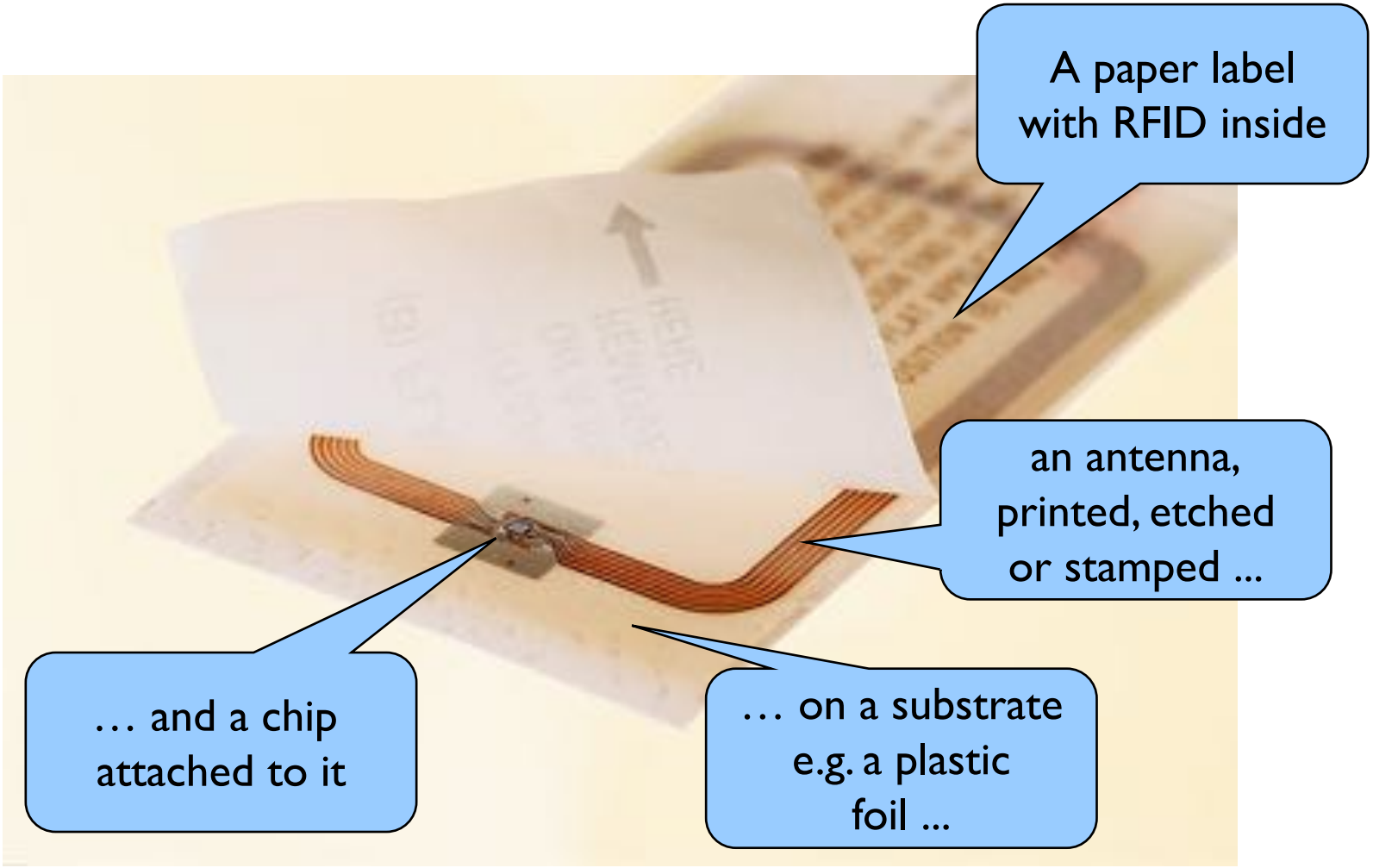
IoT Enabling Technologies: RFID

- RFID System
  - Objects equipped with RFID tag
    - Tag contains transponder with digital memory chip.
  - Interrogator: an antenna packaged with transceiver and decoder.
    - emits signal activating tag.
  - Reader detects activation signal, decodes the data on the tag's silicon chip.
  - Data passed to host computer.



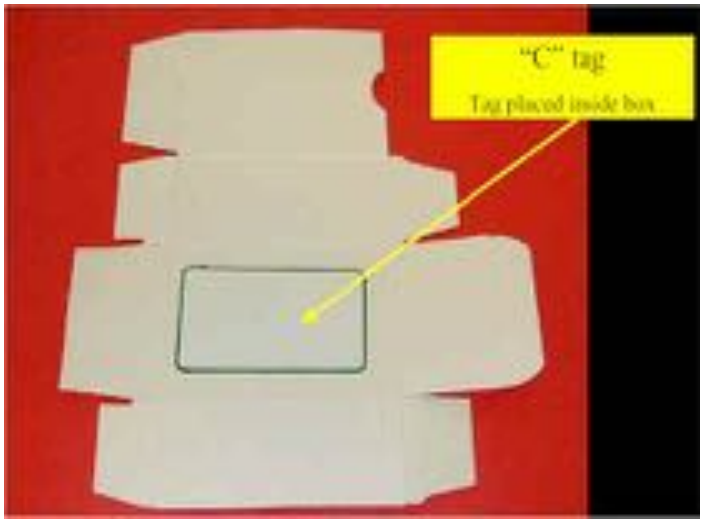
IoT Enabling Technologies: RFID

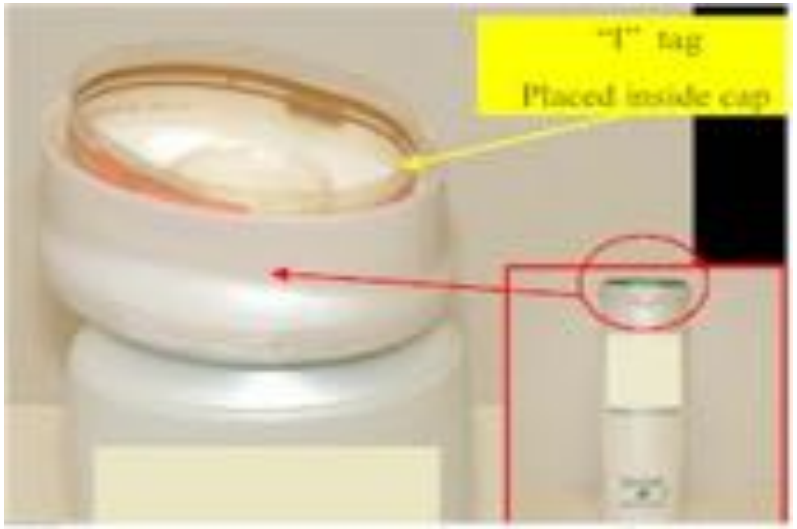
RFID tags: Smart labels



IoT Enabling Technologies: RFID

- RFID Tags
  - Contains two main parts:
    - Silicon chips
    - Antennas
- Tags can be attached to almost anything:
  - Items, cases or pallets of products, high value goods
  - vehicles, assets, livestock or personnel





IoT Enabling Technologies: RFID

- Keys or Key Fobs, Watches – access control

IoT Enabling Technologies: RFID

- Glass Transponders can be implanted under skin

IoT Enabling Technologies: RFID

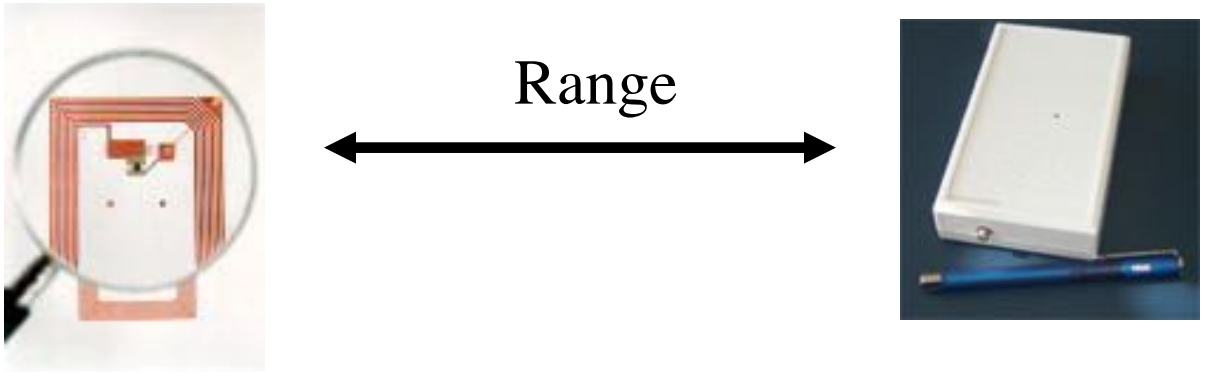
- **Passive Tags**
  - Do not require power
  - Lower storage capacities (few bits to 1 KB)
  - Shorter read ranges (4 inches to 15 feet)
  - Usually Write-Once-Read-Many/Read-Only tags
  - Cost around 25 cents to few dollars
- **Active Tags**
  - Battery powered
  - Higher storage capacities (512 KB)
  - Longer read range (300 feet)
  - Typically can be re-written by RF Interrogators
  - Cost around 50 to 250 dollars

IoT Enabling Technologies: RFID

Readers

Range

- Range – the working distance between a tag and a reader
- The range that can be achieved in an RFID system is determined by
  - The power available at the reader
  - The power available within the tag
  - The environmental conditions and structures



Frequency Bands

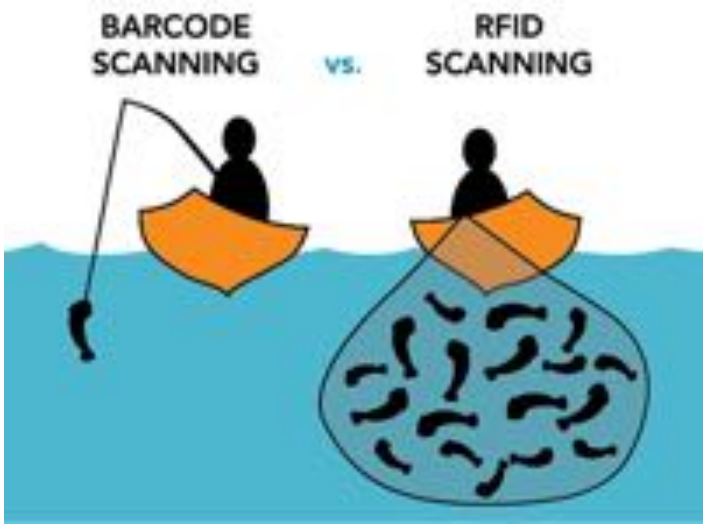
Frequency Band	Characteristics	Typical Applications
Low 100-500 kHz	Short to medium read range, inexpensive, low reading speed	Access control Animal/Human identification Inventory Control
Medium 10-15 MHz	Short to medium read range Potentially inexpensive Medium reading speed	Smart Cards
High UHF: 850-950MHz Microwave: 2.4 – 5.8 GHz	Long read range High reading speed Line of sight required (Microwave) Expensive	Railroad car monitoring Toll collection systems (OGS)

IoT Enabling Technologies: RFID

- What's so special about RFID?
  - Does not require human to manually pass item over scanner.
  - More accurate inventory count.
  - Can be incorporated into product, person, animal.
  - Can track each individual item.
  - Line of sight is not required.
  - Longer read ranges.
  - Faster: hundreds of items can be scanned in one read.

IoT Enabling Technologies: RFID

Barcode		RFID
Uses a sensor and light to read data		*Uses radio waves to get data*
Barcode must be in scanner's line of sight		Does not need line of sight to get data; can be hidden
Can only read one tag at a time		Can read tens, hundreds or thousands per second
Easily replicated or counterfeited		More secure, complex design
Requires hands-on operation (labor intensive)		Automated data collection
Must be scanned in a close range		Can read from a great distance
No read/write capabilities		Read/write devices – Large amounts of data can be programmed to the tag
Susceptible to rips and other damage that may leave it unreadable		Protected by a plastic cover, making them reusable and more durable
Least expensive		More expensive
Arguably better accuracy		Vulnerable to reader or tag collision: - A single tag tries to respond to two reader signals and is unable to re spond to either - Multiple tags in area respond to a single reader simultaneously and can not process
Smaller, lighter, easier to use		
Barcodes are universal and can be pro-cessed from any barcode reader		



IoT Enabling Technologies: RFID

- Some RFID applications:
  - Wal-Mart now requires its suppliers to use RFID tags on shipping crates and pallets to improve inventory management in the supply chain.

Wal-Mart testing R.F.I.D Technology in stores !!

Supermarkets go high-tech to combat shoplifters: https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=10529798

https://www.youtube.com/watch?v=a3UlEHIpYeY

IoT Enabling Technologies: RFID

- Some RFID applications:
  - Cattle and farm animals are being tagged to improve tracking and monitoring of health.

old fashioned ear tag for identification.

NAIT in NZ (Tag your animals): http://www.nait.co.nz/tag/

IoT Enabling Technologies: RFID

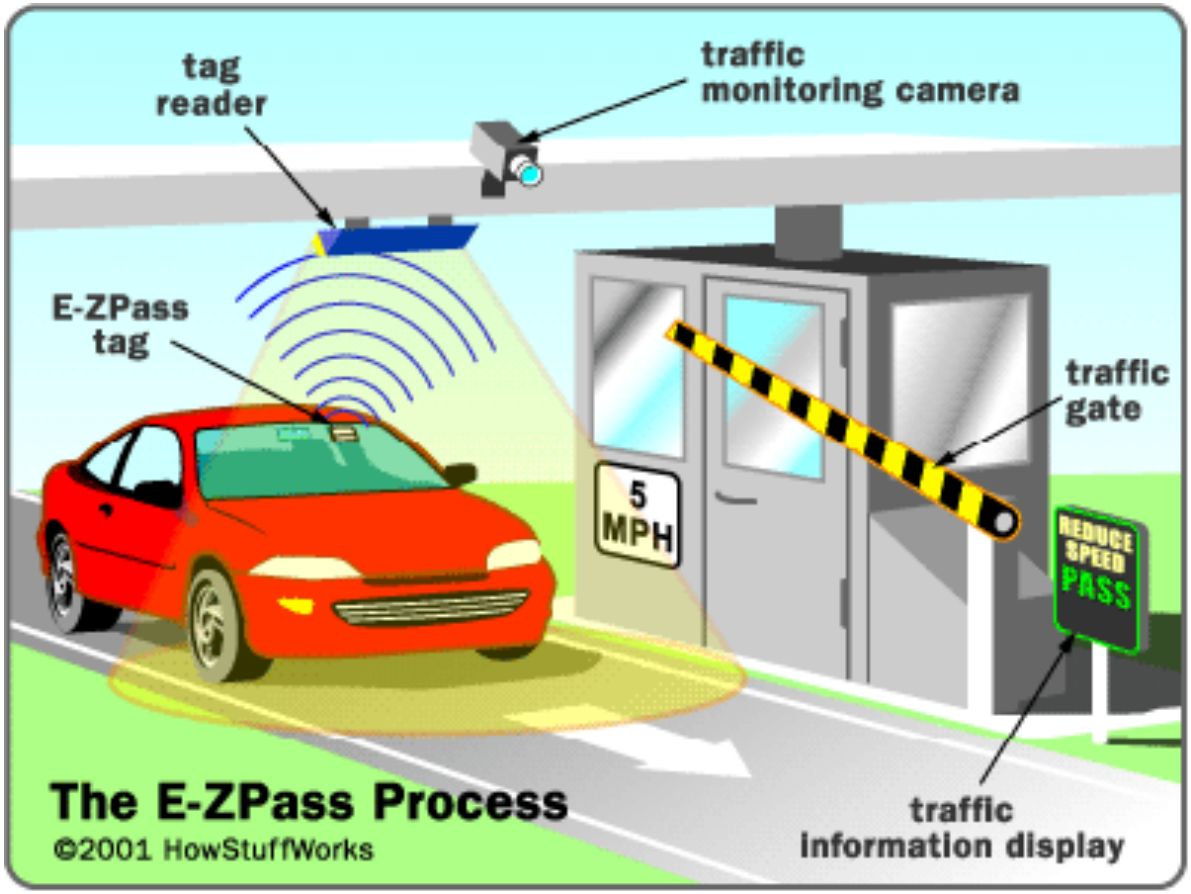
- Some RFID applications:
  - Fed Ex bought RFID-enabled aircraft from Airbus to reduce maintenance time and costs.

IoT Enabling Technologies: RFID

- Some RFID applications:
  - Electronic payment – credit card companies moving to RFID-enabled cards to increase efficiency and reduce time at point-of-sale for customer, merchant, and card issuer.

IoT Enabling Technologies: RFID

- Some RFID applications:
  - Automated Toll Collection



IoT Enabling Technologies: RFID

- Some RFID future applications:
  - Smart Grocery Store
    - Several carts this full in early evening could seriously slow down the checkout process.
    - How much do cashiers cost?
    - Add an RFID tag to all items in the grocery.
    - As the cart leaves the store, it passes through an RFID transceiver
    - The cart is rung up in seconds.

IoT Enabling Technologies: RFID

- RFID future applications:
  - Smart Groceries Enhanced
    - Track products through their entire lifetime.

IoT Enabling Technologies: RFID

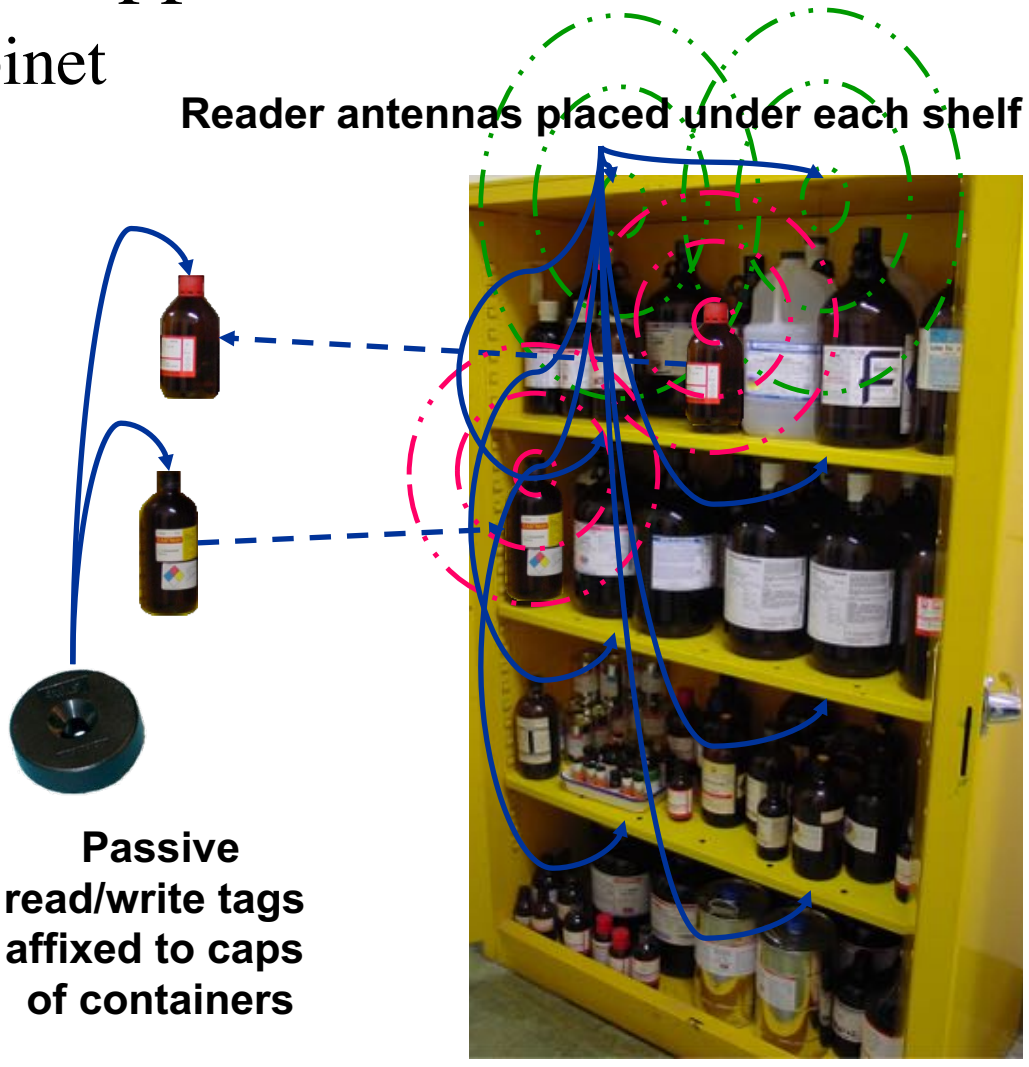
- RFID future applications:
  - RFID Chef
    - Uses RFID tags to recognize food in your kitchen
    - Shows you the recipes that most closely match what is available
    - Distributed Systems Group ETH – Zurich, Switzerland

IoT Enabling Technologies: RFID

- RFID future applications:
  - Smart Fridge
    - Recognizes what's been put in it
    - Recognizes when things are removed
    - Creates automatic shopping lists
    - Notifies you when things are past their expiration
    - Shows you the recipes that most closely match what is available

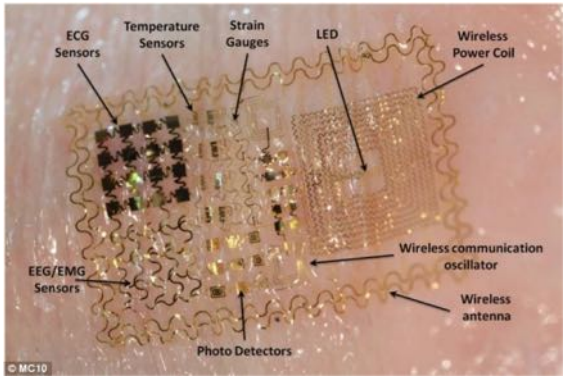
IoT Enabling Technologies: RFID

- RFID future applications:
  - Smart cabinet



IoT Enabling Technologies: RFID

- "Smart" products:
  - Clothing, appliances, CDs, etc. tagged for store returns.
- "Smart" house:
  - Smart keys, Intelligent washing machines, Monitoring refrigerators, Intelligent ovens/microwaves
  - Closets that advice on style depending on clothes available.
- "Smart" hospital:
  - Drug Counterfeiting, Medical "Passports", Food Chain Precautions
- "Smart" people ??



IoT Enabling Technologies: RFID

- RFID's Advantages
  - Passive
    - wireless
  - Store data on a tag
  - Can be hidden
  - Work in harsh environments
  - Low cost?

IoT Enabling Technologies: RFID

- RFID's Disadvantages
  - Lack of standards!
  - Short range
  - Cost

Outline

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    - Big Data
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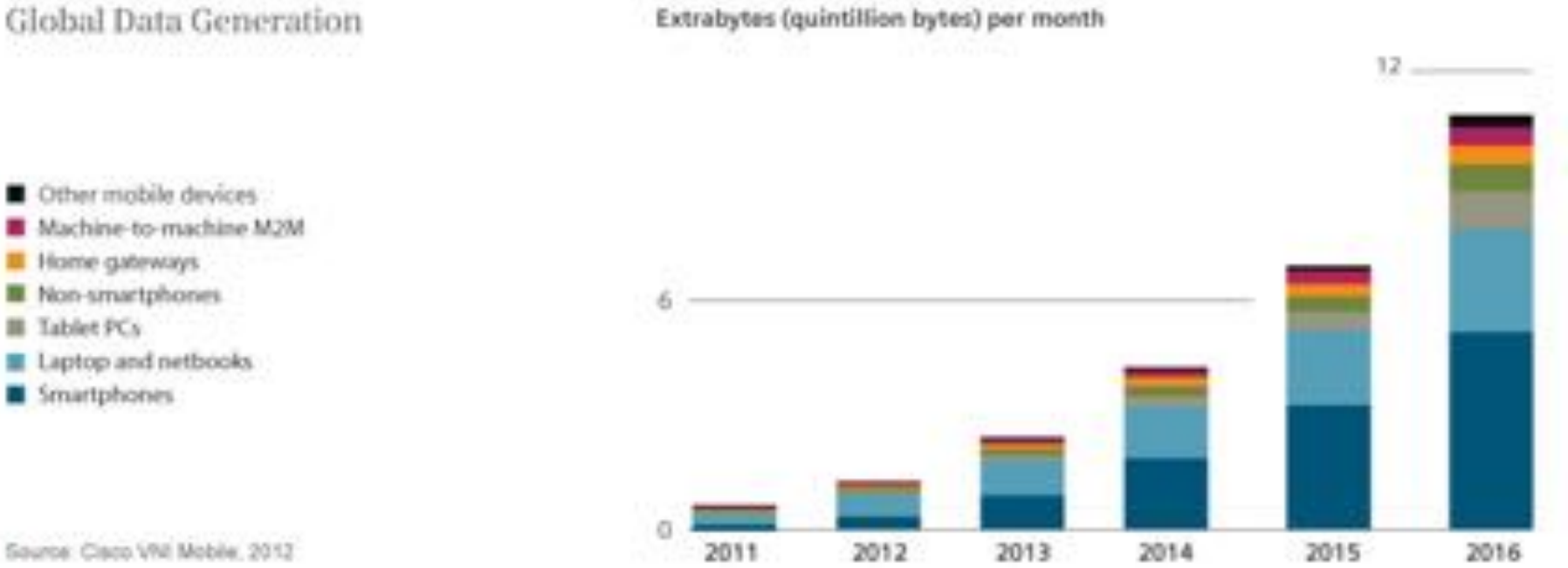
IoT Enabling Technologies: Big Data

IoT Enabling Technologies: Big Data

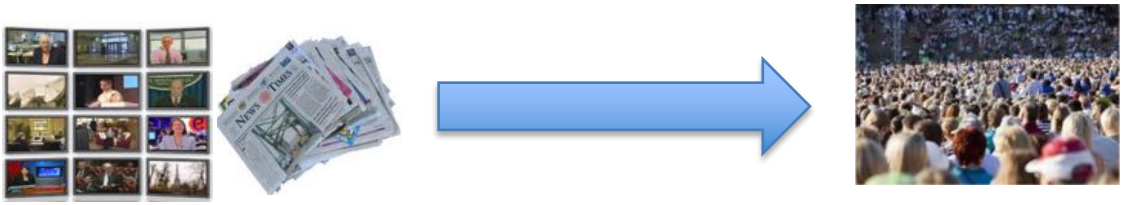
- Everyday around 20 quintillion (10^18) bytes of data are produced. (Source: http://www-01.ibm.com/software/data/bigdata/).
- This data includes textual content (unstructured, semi-structured, structured) to multimedia content (images, video and audio), on a variety of platforms (enterprise, social media, and sensors).



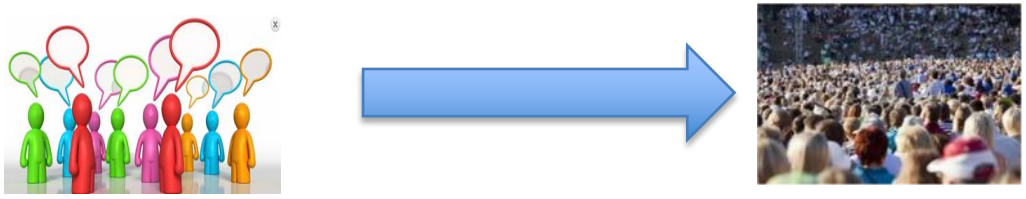
IoT Enabling Technologies: Big Data

- **The Model of Generating/Consuming Data has Changed**

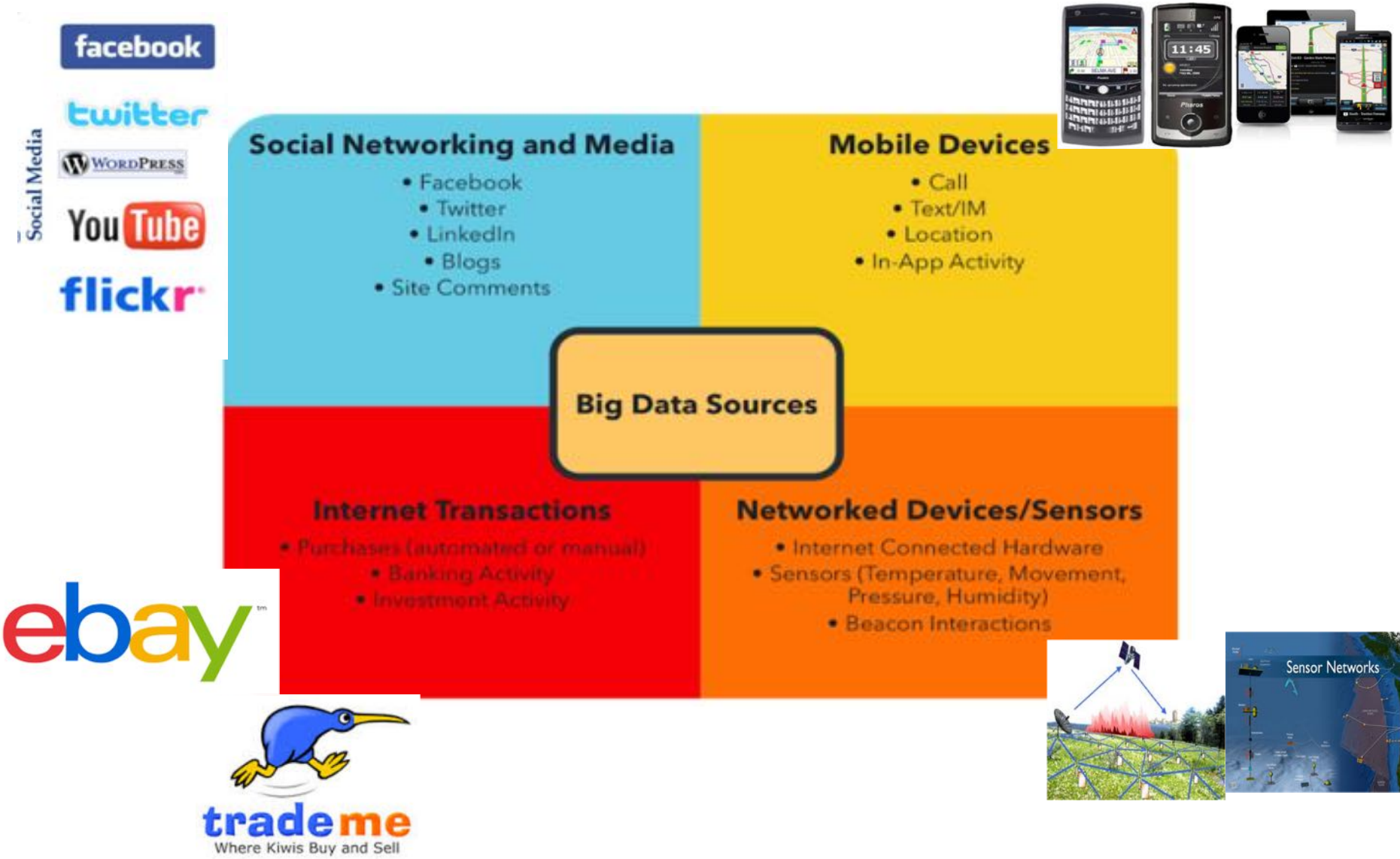
Old Model: Few companies are generating data, all others are consuming data



New Model: all of us are generating data, and all of us are consuming data



IoT Enabling Technologies: Big Data



IoT Enabling Technologies: Big Data

Who's Generating Big Data

Social media and networks
(all of us are generating data)

Scientific instruments
(collecting all sorts of data)

Mobile devices
(tracking all objects all the time)

Sensor technology and networks
(measuring all kinds of data)

- The progress and innovation is no longer hindered by the ability to collect data
- But, by the ability to manage, analyze, summarize, visualize, and discover knowledge from the collected data in a timely manner and in a scalable fashion

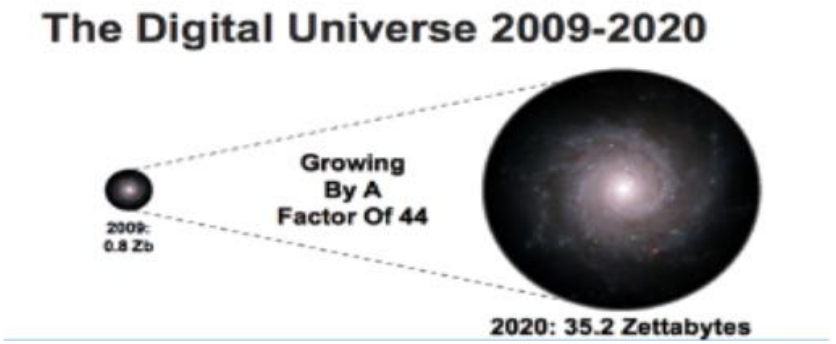
IoT Enabling Technologies: Big Data

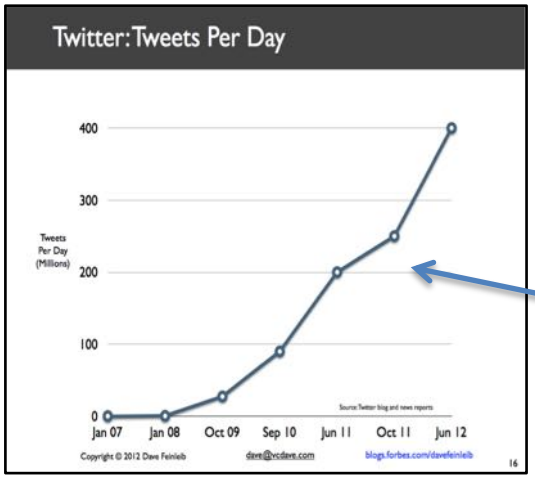
- No single standard definition…

"***Big Data***" is data whose scale, diversity, and complexity require new architecture, techniques, algorithms, and analytics to manage it and extract value and hidden knowledge from it…

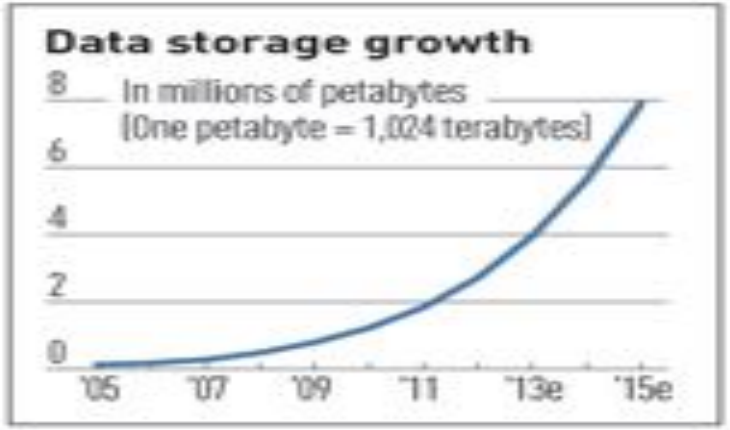
Characteristics of Big Data:
1-Scale (Volume)

- **Data Volume**
  - 44x increase from 2009 to 2020
- Data volume is increasing exponentially



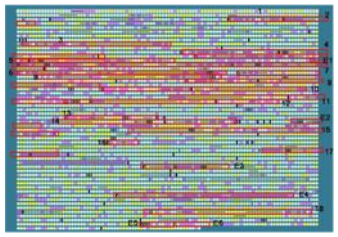


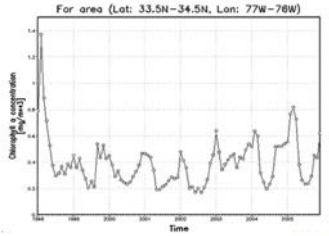
Exponential increase in collected/generated data

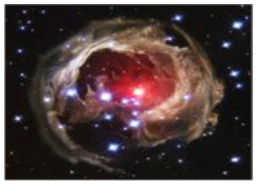


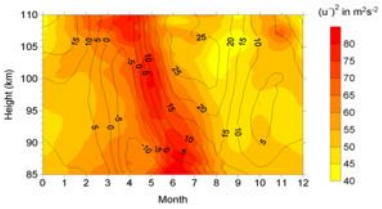
Characteristics of Big Data:
2-Complexity (Variety)

- Various formats, types, and structures
- Text, numerical, images, audio, video, sequences, time series, social media data, multi-dim arrays, etc…
- A single application can be generating/collecting many types of data







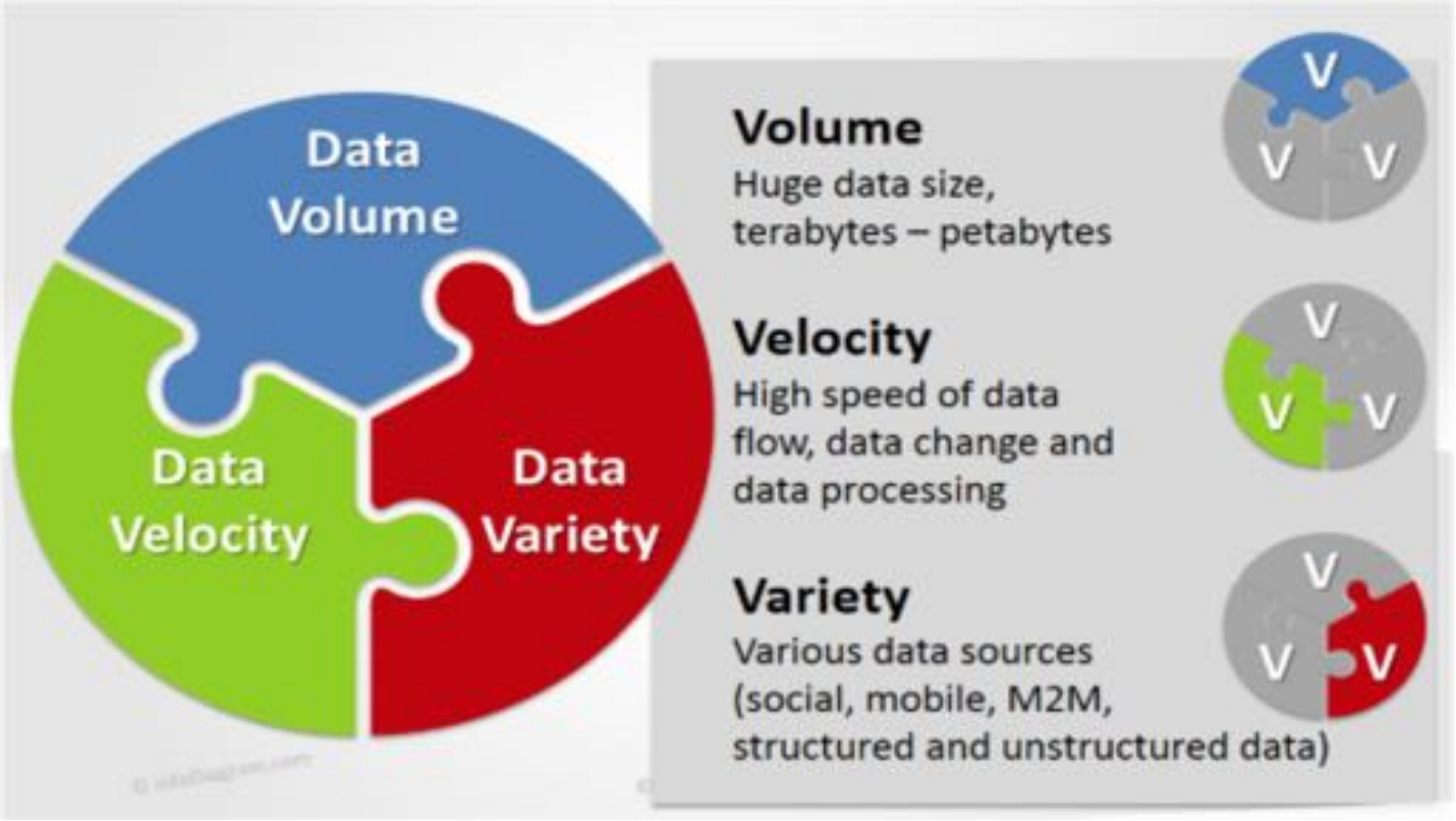


To extract knowledge➔ all these types of data need to linked together

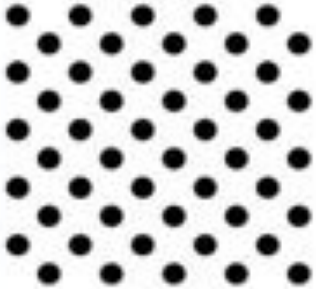
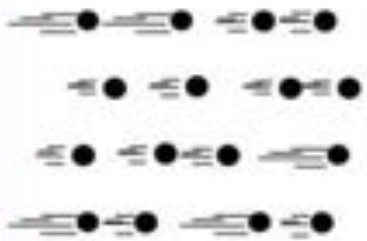
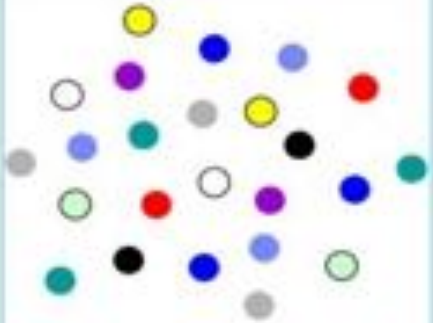
Characteristics of Big Data:
3-Speed (Velocity)

- Data is generated fast and need to be processed fast
- Late decisions ➔ missing opportunities
- **Examples**
  - **E-Promotions:** Based on your current location, your purchase history, what you like ➔ send promotions right now for store next to you
  - **Healthcare monitoring:** sensors monitoring your activities and body ➔ any abnormal measurements require immediate reaction

Big Data Characteristics



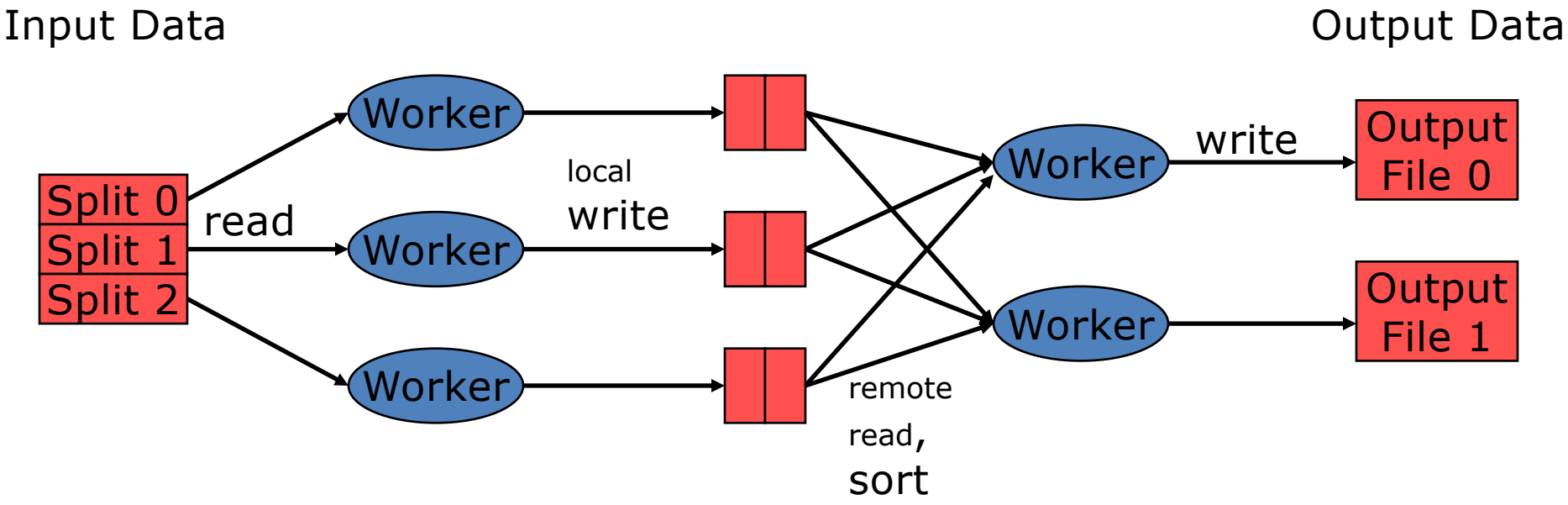
Some Make it 4V's

Volume	Velocity	Variety	Veracity*
			
Data at Rest	**Data in Motion**	**Data in Many Forms**	**Data in Doubt**
Terabytes to exabytes of existing data to process	Streaming data, milliseconds to seconds to respond	Structured, unstructured, text, multimedia	Uncertainty due to data inconsistency & incompleteness, ambiguities, latency, deception, model approximations

MapReduce Programming Model

- A single machine cannot serve all the data
- Need a distributed system to store and process **in parallel**
- How do you scale to more machines?
- **MapReduce** - programming model and an associated implementation for processing and generating big data sets with a parallel, distributed algorithm on a cluster
- How does MapReduce work?
  - Read a lot of data
  - Map: extract something you care about from each record
  - Shuffle and Sort
  - Reduce: aggregate, summarize, filter, or transform
  - Write the results

MapReduce workflow



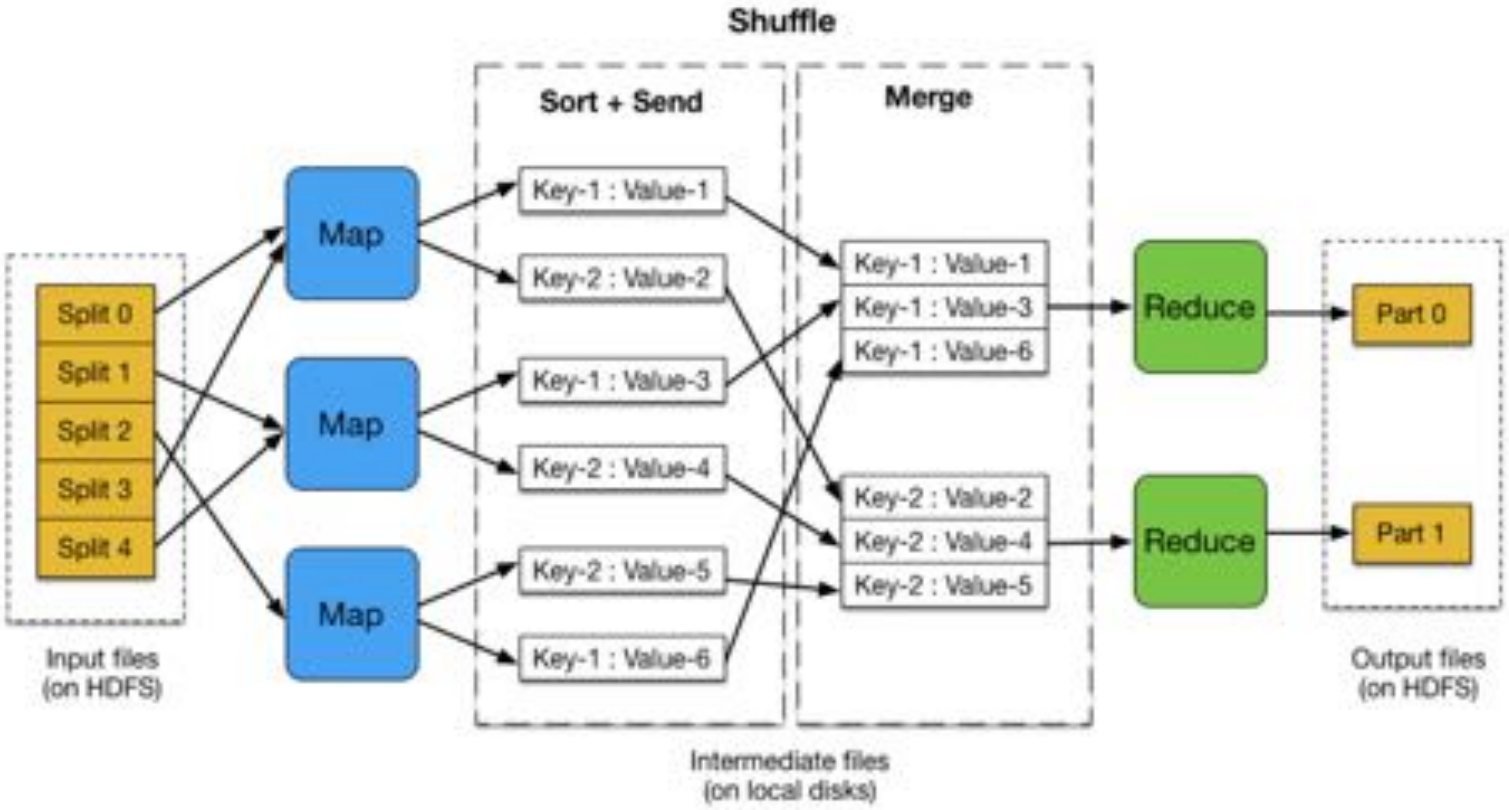
Map
extract something you care about from each record

Reduce aggregate, summarize, filter, or transform

Example: Word Count

http://kickstarthadoop.blogspot.ca/2011/04/word-count-hadoop-map-reduce-example.html

MapReduce Programming Model



Outline

- This Lecture
  - Internet of Things
    - RFID
    - Big Data
  - Software-defined Networks (SDN)

Outline

- This Lecture
  - Internet of Things
    - RFID
    - Big Data
  - Software-defined Networks
    - What is SDN?
    - What is OpenFlow?

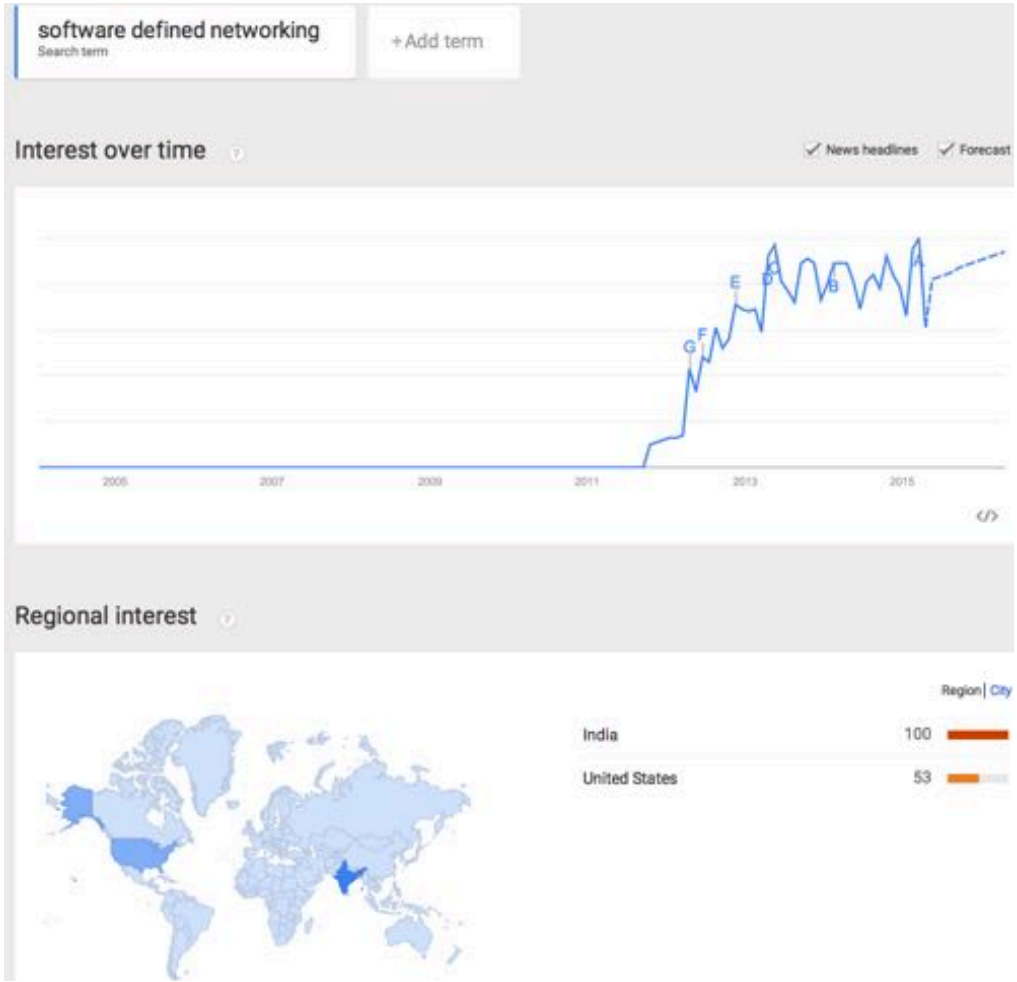
What is SDN? Networking Trends

- **Software-defined Networking** Google trends:

✓ Large amount of searches from 2012, Increasing

✓ USA and India are highly correlated probably because Indian IT industry services US companies

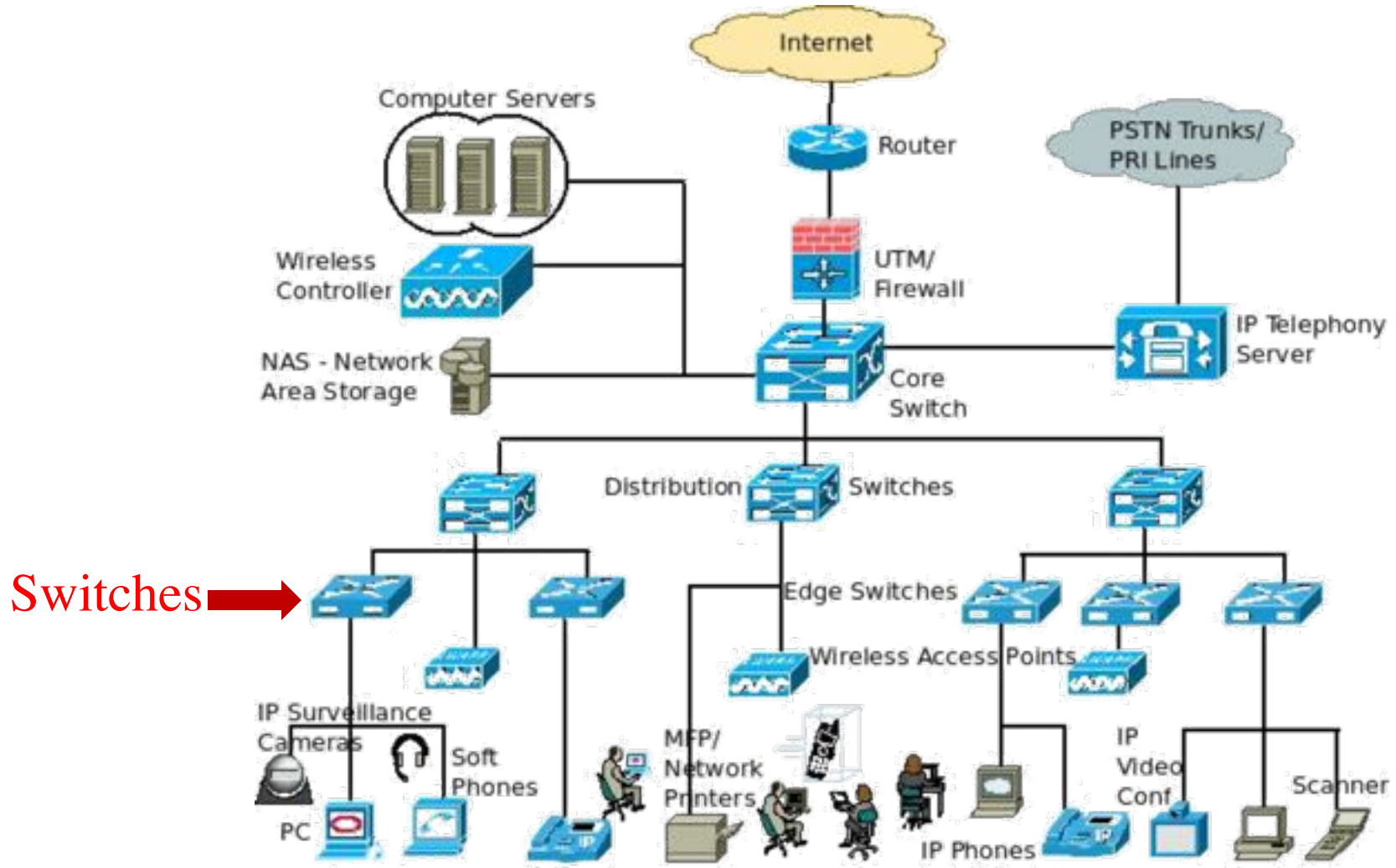
✓ Forecast: increasing



What is SDN? Limitations of Current Networks

https://www.youtube.com/watch?v=53djBGNDXl0

Limitations of Current Networks



http://www.excitingip.net/27/a-basic-enterprise-lan-network-architecture-block-diagram-and-components/

What is SDN? Limitations of Current Networks

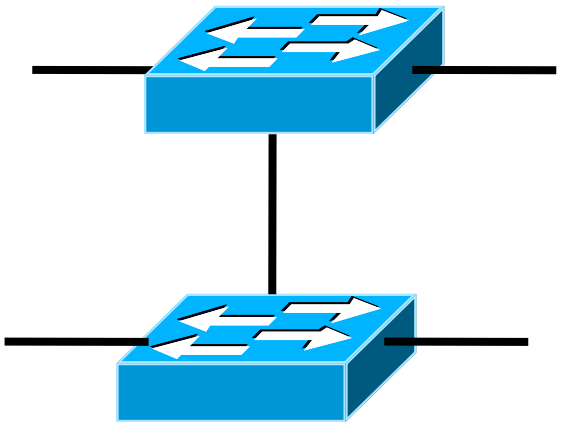
- **No control plane abstraction for the whole network!**

- **It's like old times – when there was no OS…**

Wilkes with the EDSAC, 1949

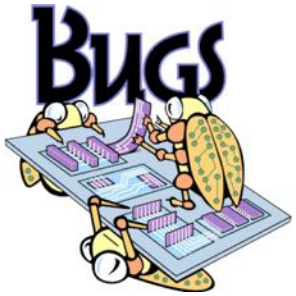
What is SDN? Limitations of Current Networks

- Limitations of Current Networks
  - Enterprise networks are difficult to manage
    - How to easily configure huge networks?
  - Closed equipment
    - Software bundled with hardware
  - Over specified
    - Slow protocol standardization
  - Few people can innovate
    - Equipment vendors write the code
    - Long delays to introduce new feature



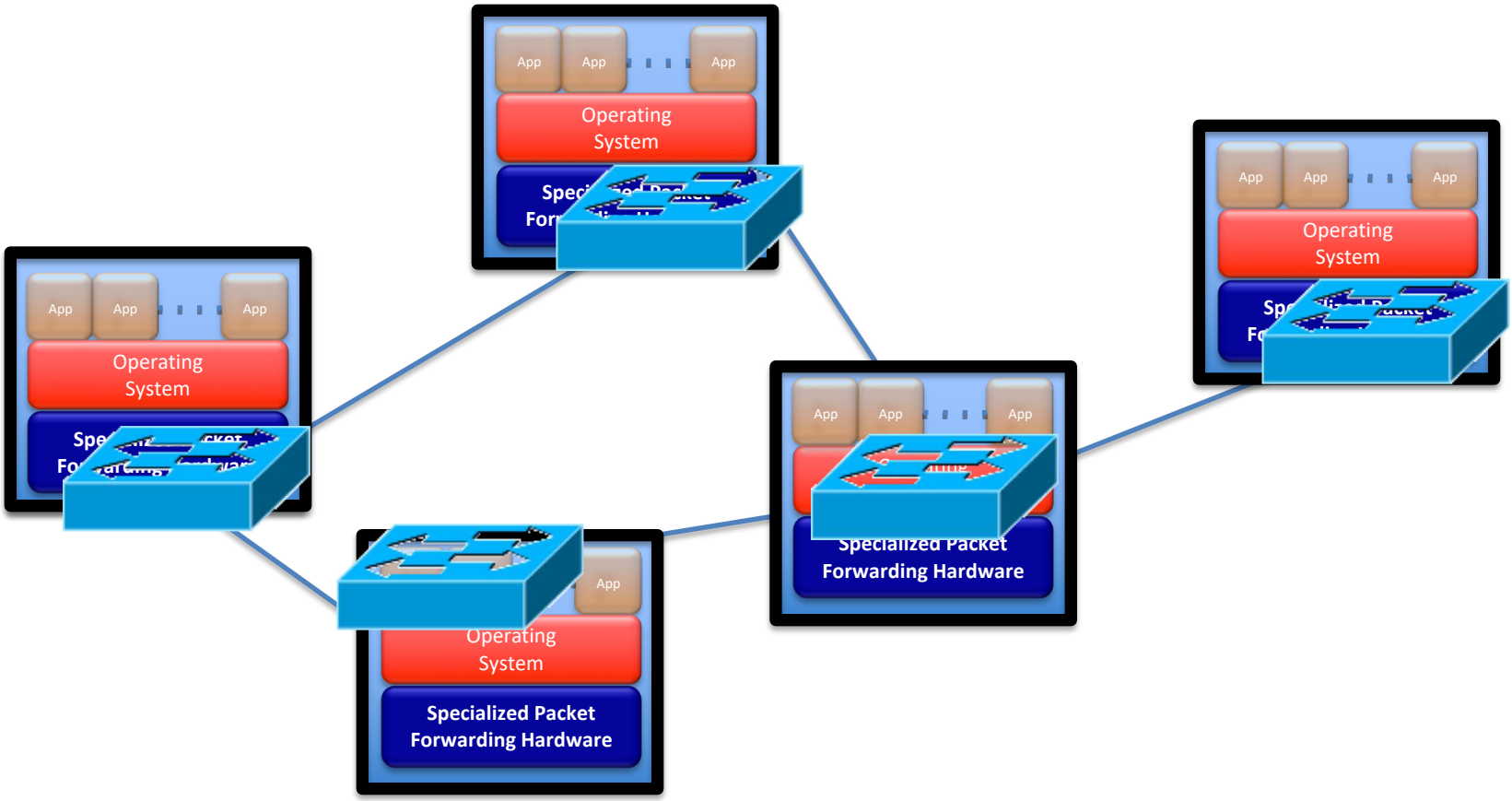
What is SDN? Limitations of Current Networks

- Networks are Hard to Manage
  - Operating a network is expensive
    - More than half the cost of a network
    - operator error causes most outages
  - Buggy software in the equipment
    - Routers with 20+ million lines of code
    - Cascading failures, vulnerabilities, etc.
  - The network is "in the way"
    - Especially a problem in data centers



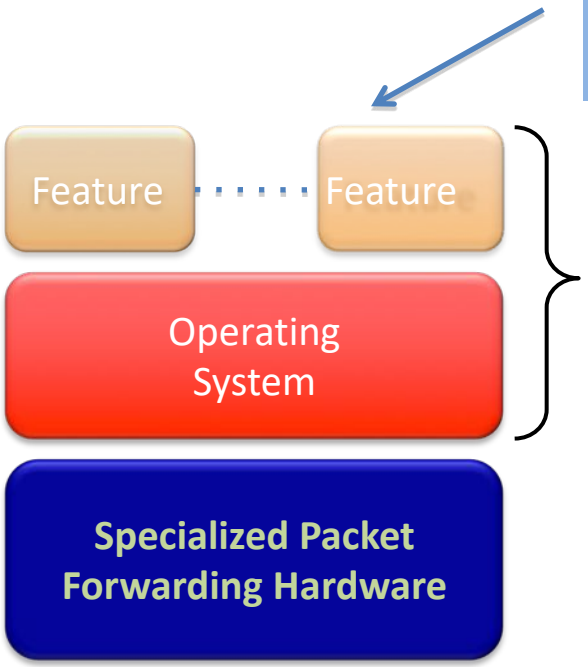
What is SDN? An OS for Networks

- **Old ways to configure a network**



What is SDN? An OS for Networks

Routing, management, mobility management,
access control, …



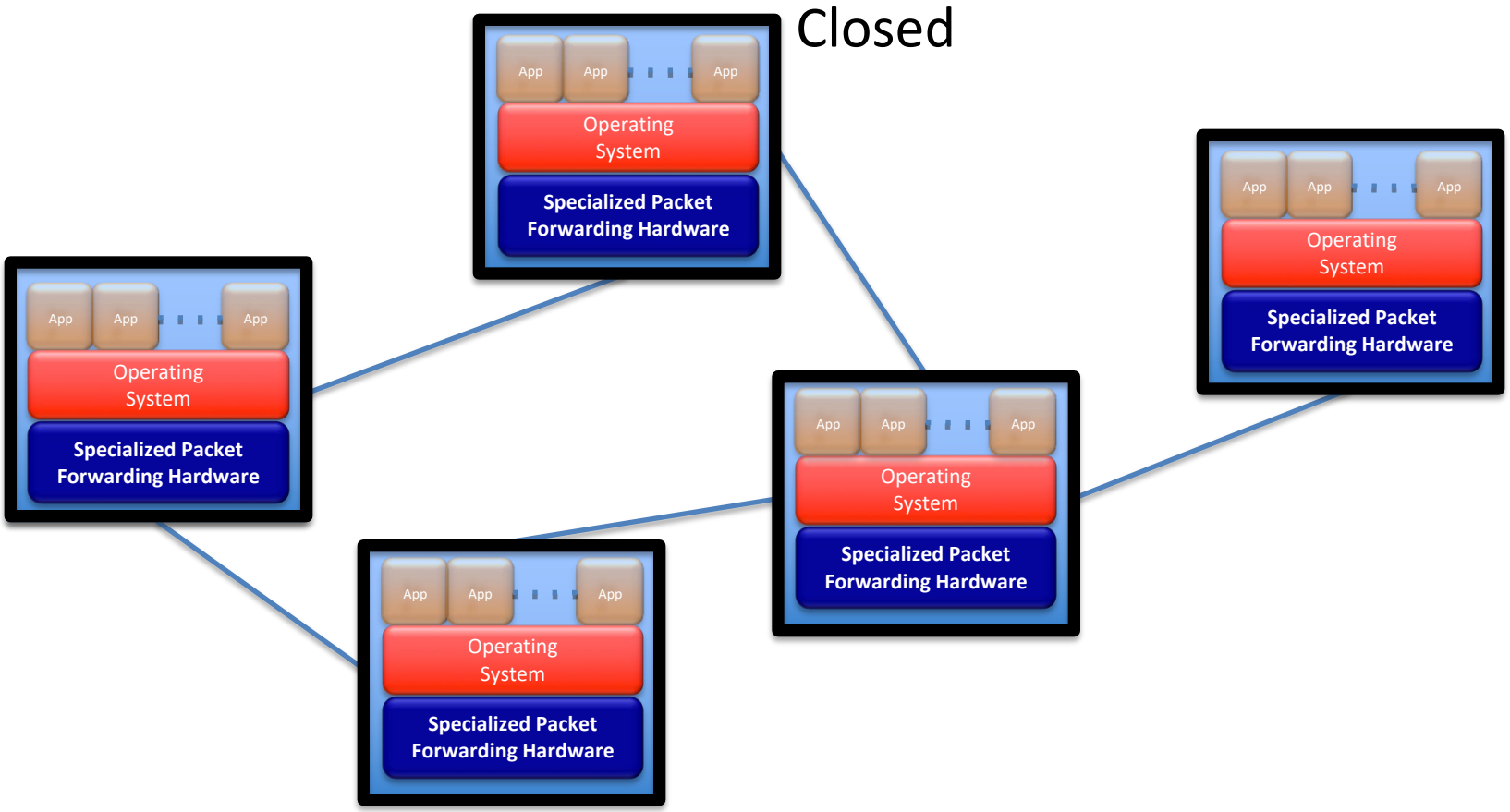
Million of lines of source code

Many complex functions baked into infrastructure

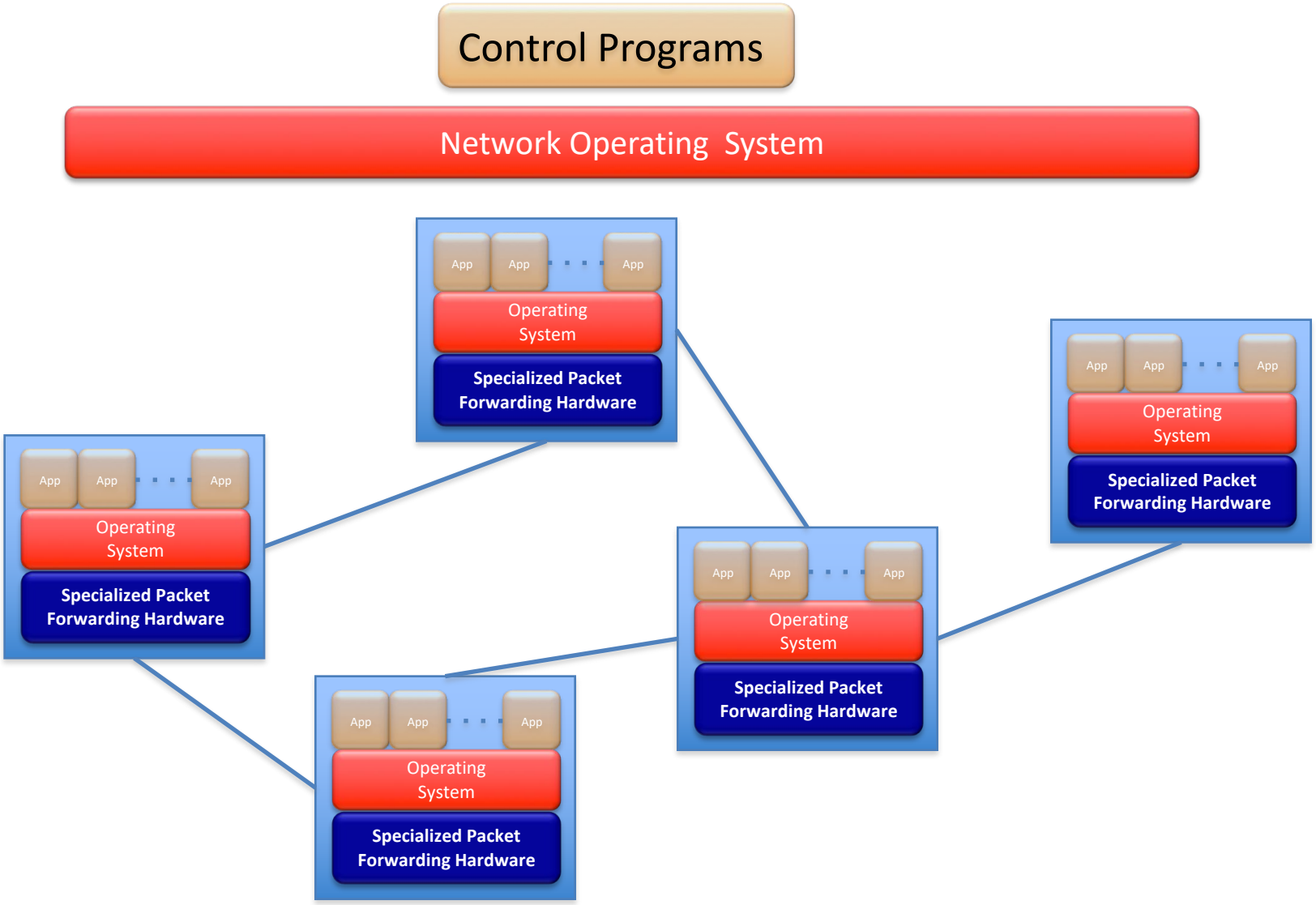
Cannot dynamically change according to network conditions

What is SDN? An OS for Networks

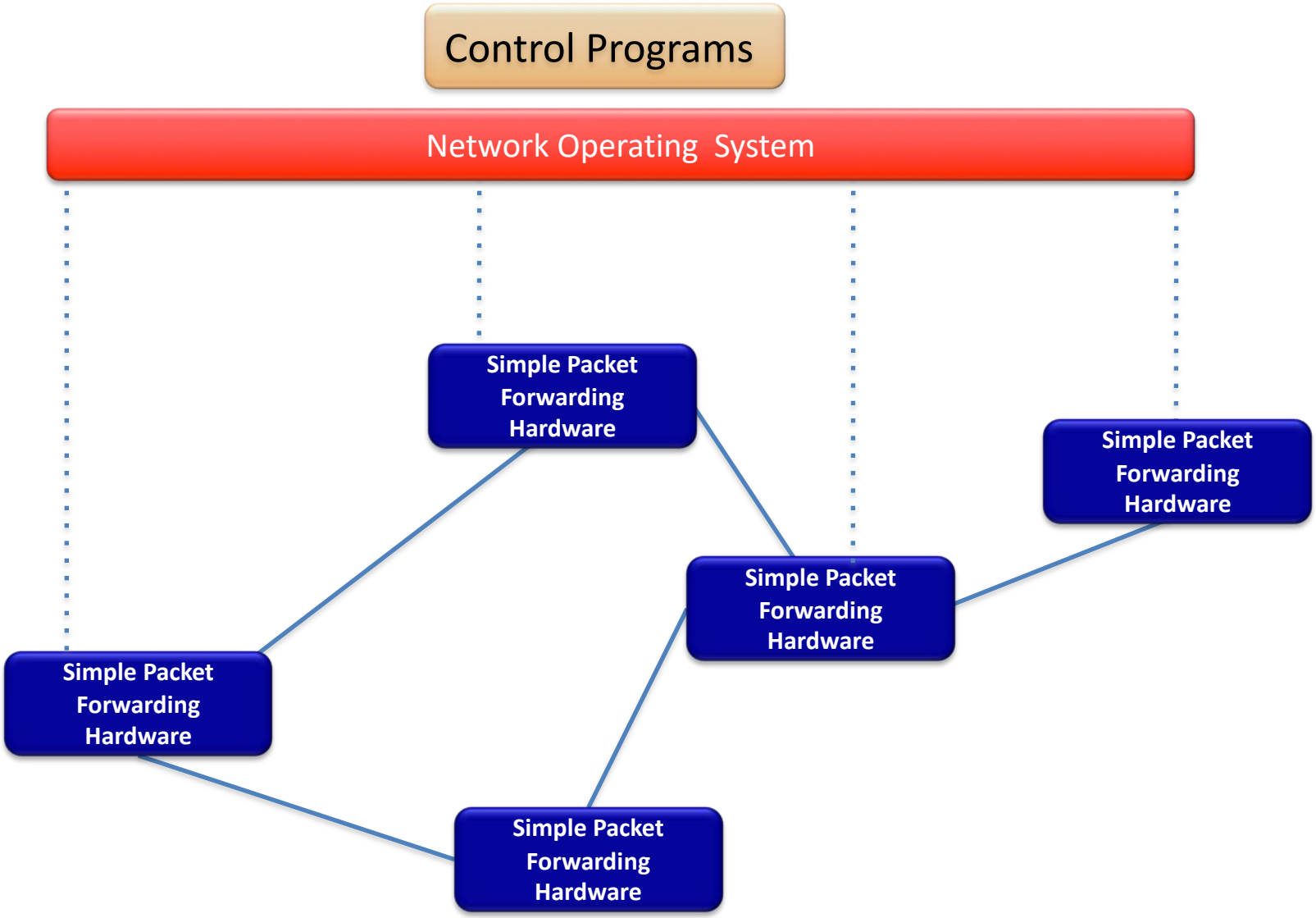
Idea: An OS for Networks



What is SDN? An OS for Networks



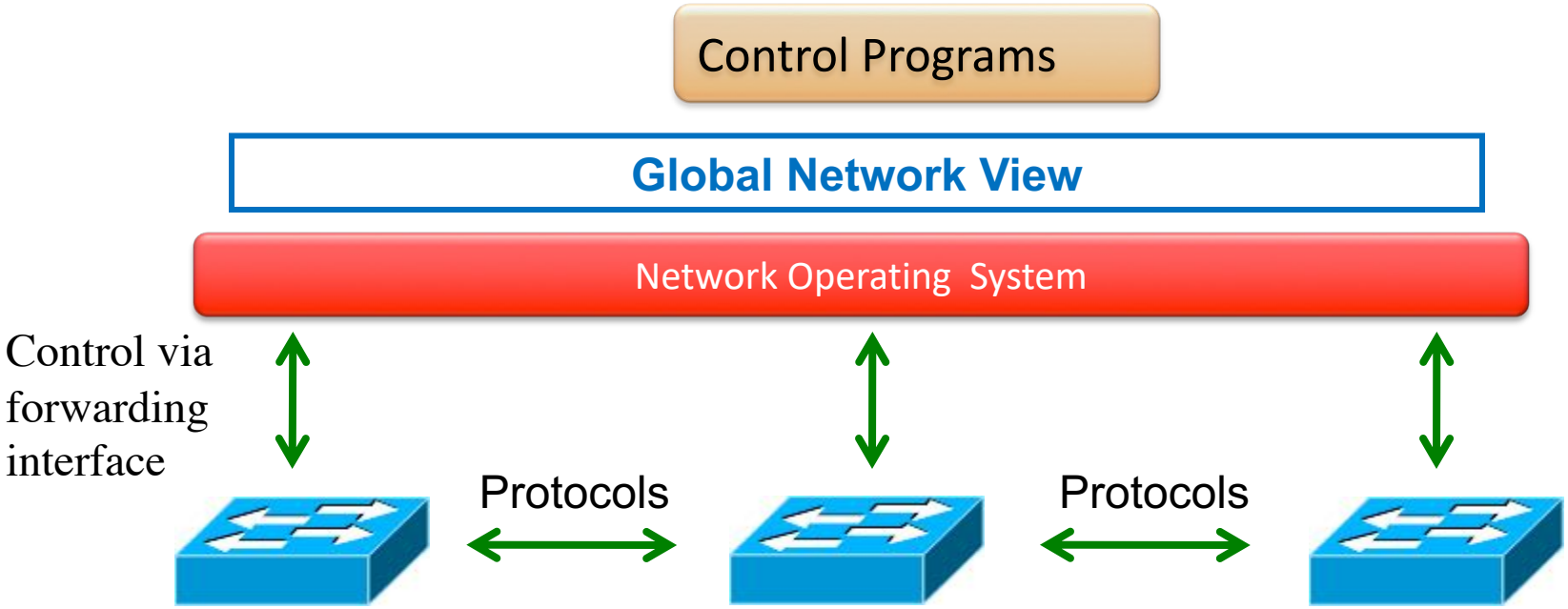
What is SDN? An OS for Networks



What is SDN? An OS for Networks

- **Towards an Operating System for Networks:**

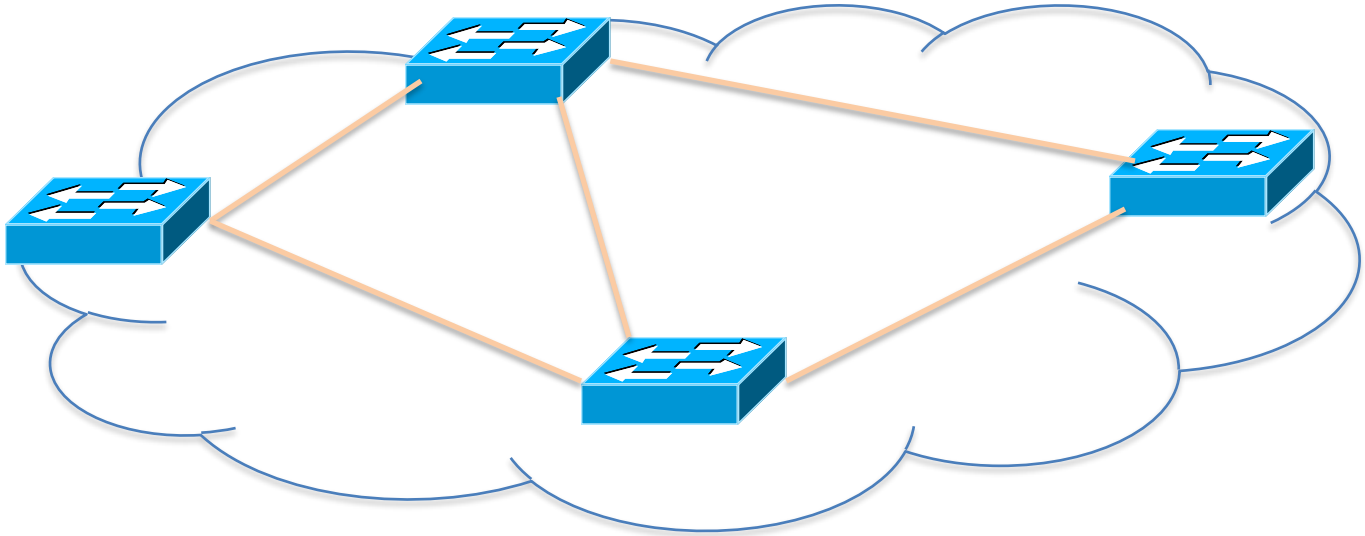
Software-Defined Networking (SDN)



Rethinking the “Division of Labor”

What is SDN? An OS for Networks

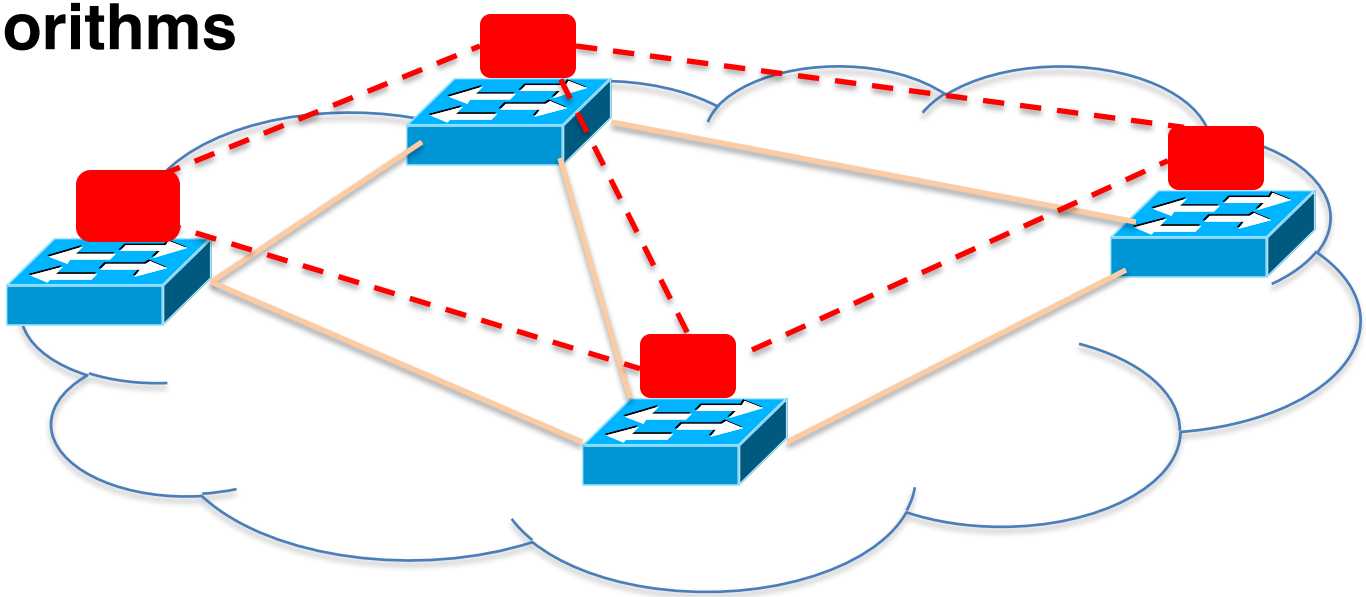
Data plane:
Packet streaming



Forward, filter, buffer, mark,
rate-limit, and measure packets

What is SDN? An OS for Networks

Control plane:
Distributed algorithms

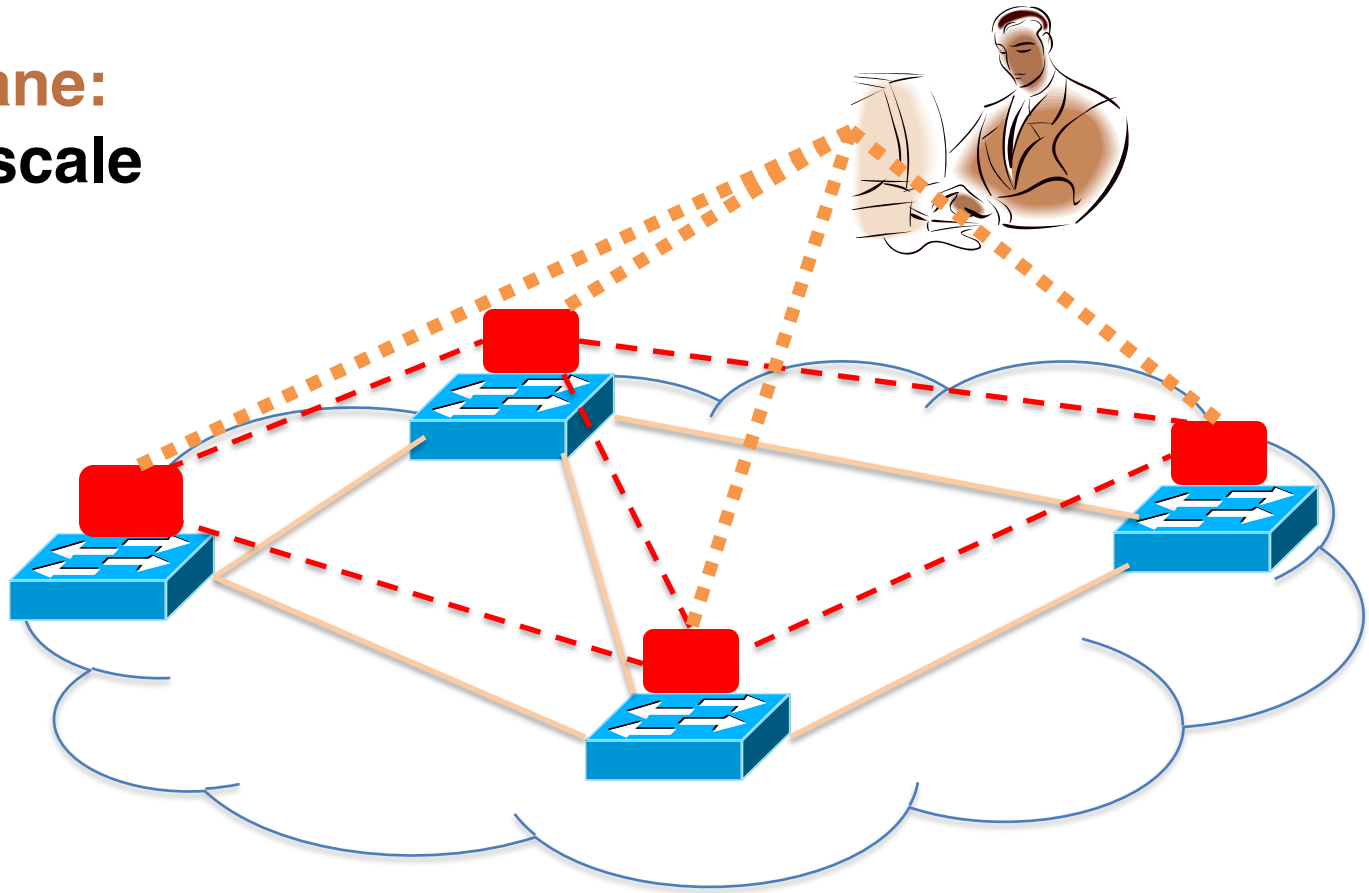


Track topology changes, compute routes, install forwarding rules

What is SDN? An OS for Networks

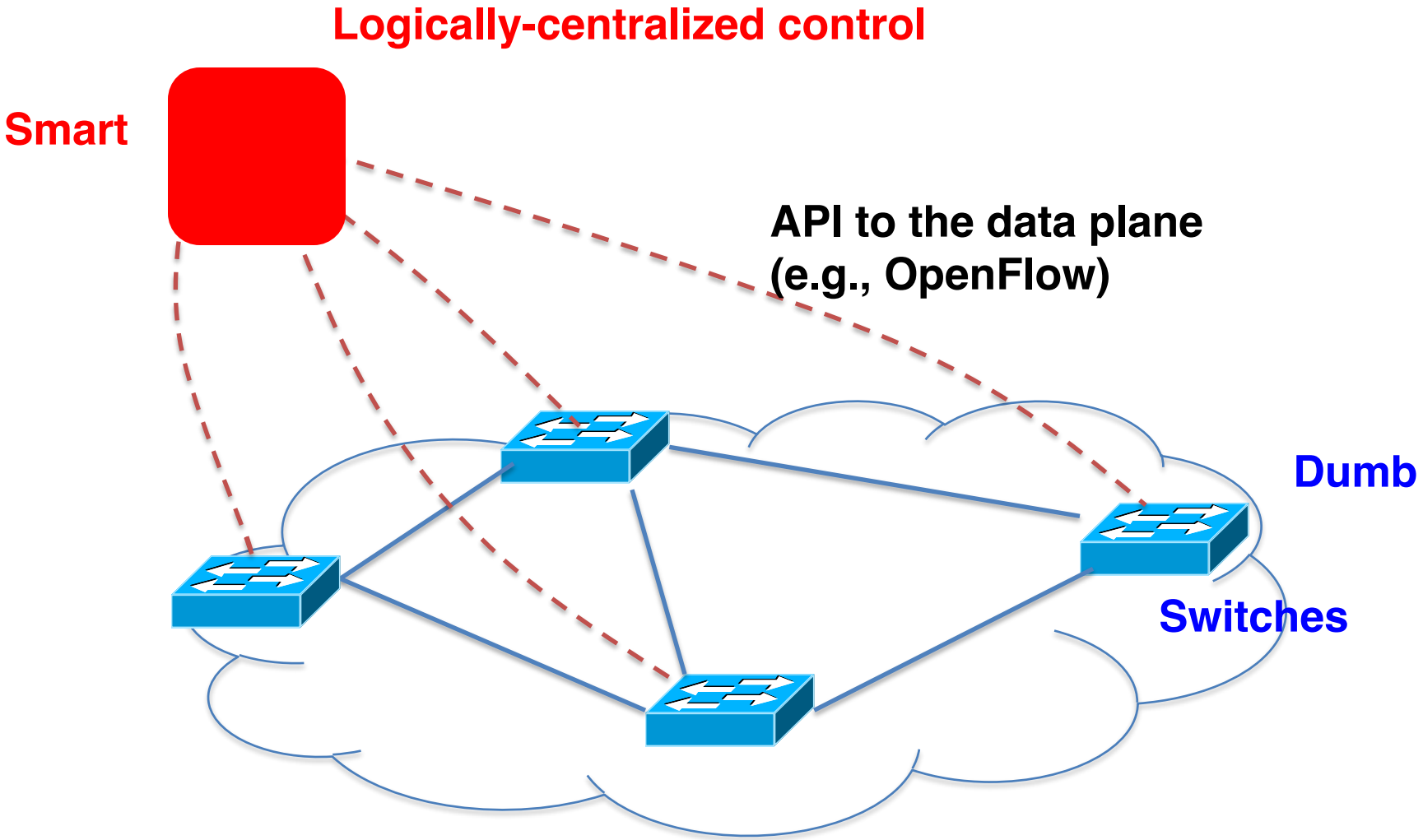
Management plane:

Human time scale



Collect measurements and configure the equipment

What is SDN? An OS for Networks



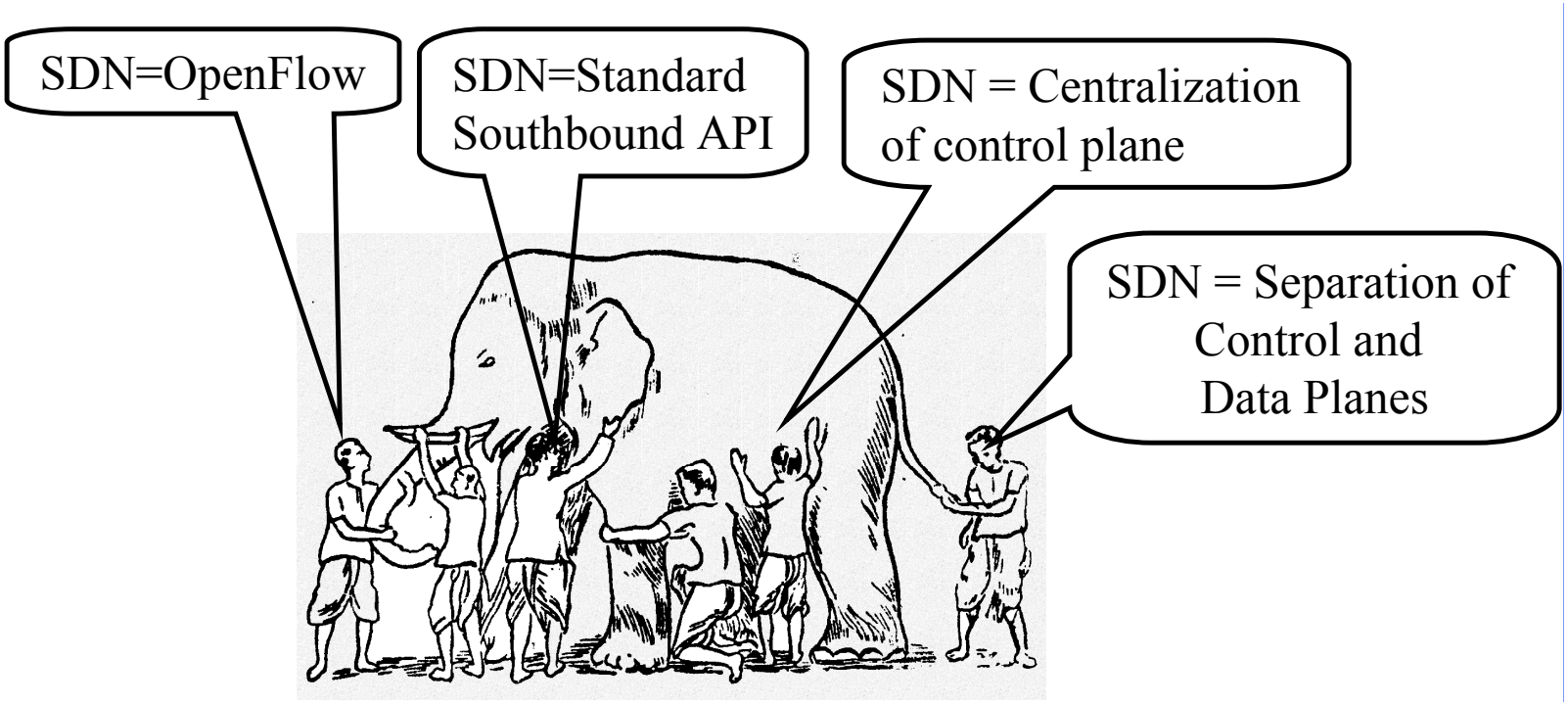
What is SDN? An OS for Networks

- **No longer designing distributed control protocols**
- **Much easier to write, verify, maintain, …**
  - An interface for programming
- **NOS serves as fundamental control block**
  - With a global view of network

What is SDN? An OS for Networks

- Possible definitions:
  - SDN is a new network architecture:
    - that's makes it easier to program networks.
    - with the core idea that software remotely controls network hardware.
  - SDN is a framework to allow network administrators to automatically and dynamically manage and control a large number of network devices, services, topology, traffic paths, and packet handling (quality of service) policies using high-level languages and APIs. Management includes provisioning, operating, monitoring, optimizing, and managing FCAPS (faults, configuration, accounting, performance, and security).

What is SDN? An OS for Networks

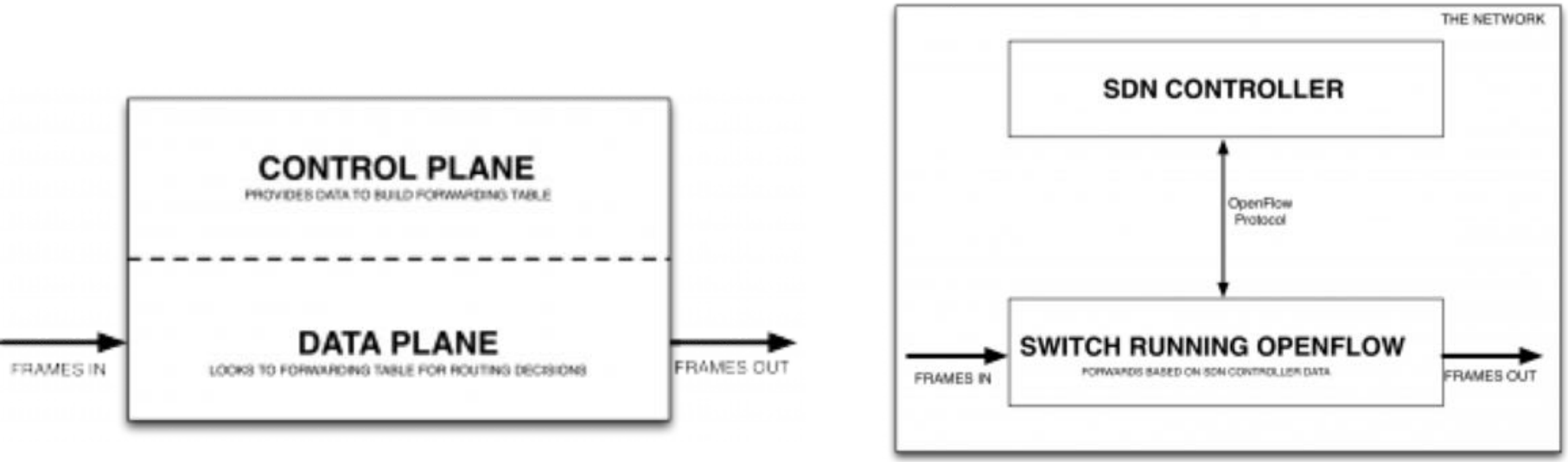


What is SDN? Why

- Why we need SDN?
  - Virtualization: Use network resource without worrying about where it is physically located, how much it is, how it is organized, etc.
  - Orchestration: Should be able to control and manage thousands of devices by commands.
  - Programmable: Should be able to change behavior on the fly.
  - Dynamic Scaling: Should be able to change size, quantity
  - Automation: To minimize manual involvement

What is SDN?

- Traditional vs Software Defined Networking



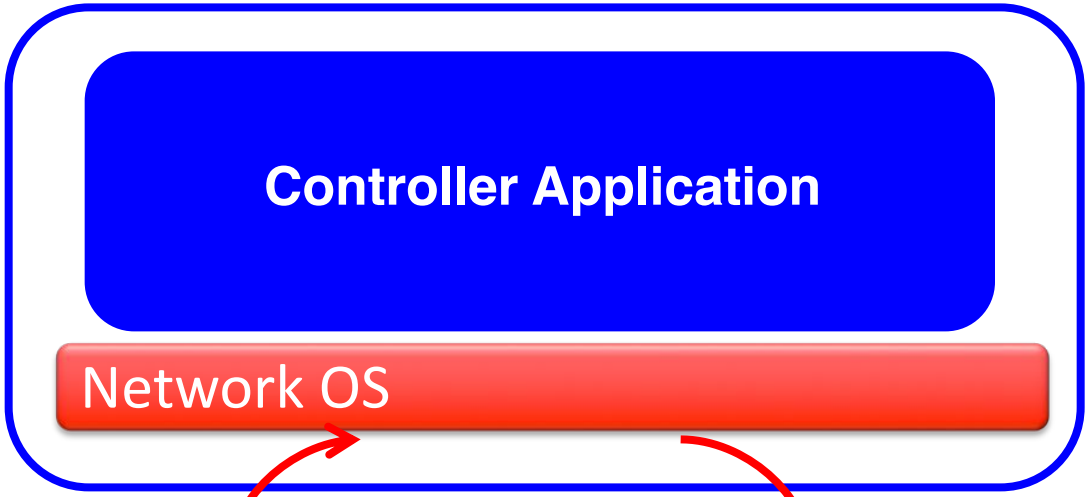
Outline

- This Lecture
  - Software-defined Networks
    - What is SDN?
    - What is OpenFlow?

What is OpenFlow?

https://www.youtube.com/watch?v=CMtuAsm5ApA

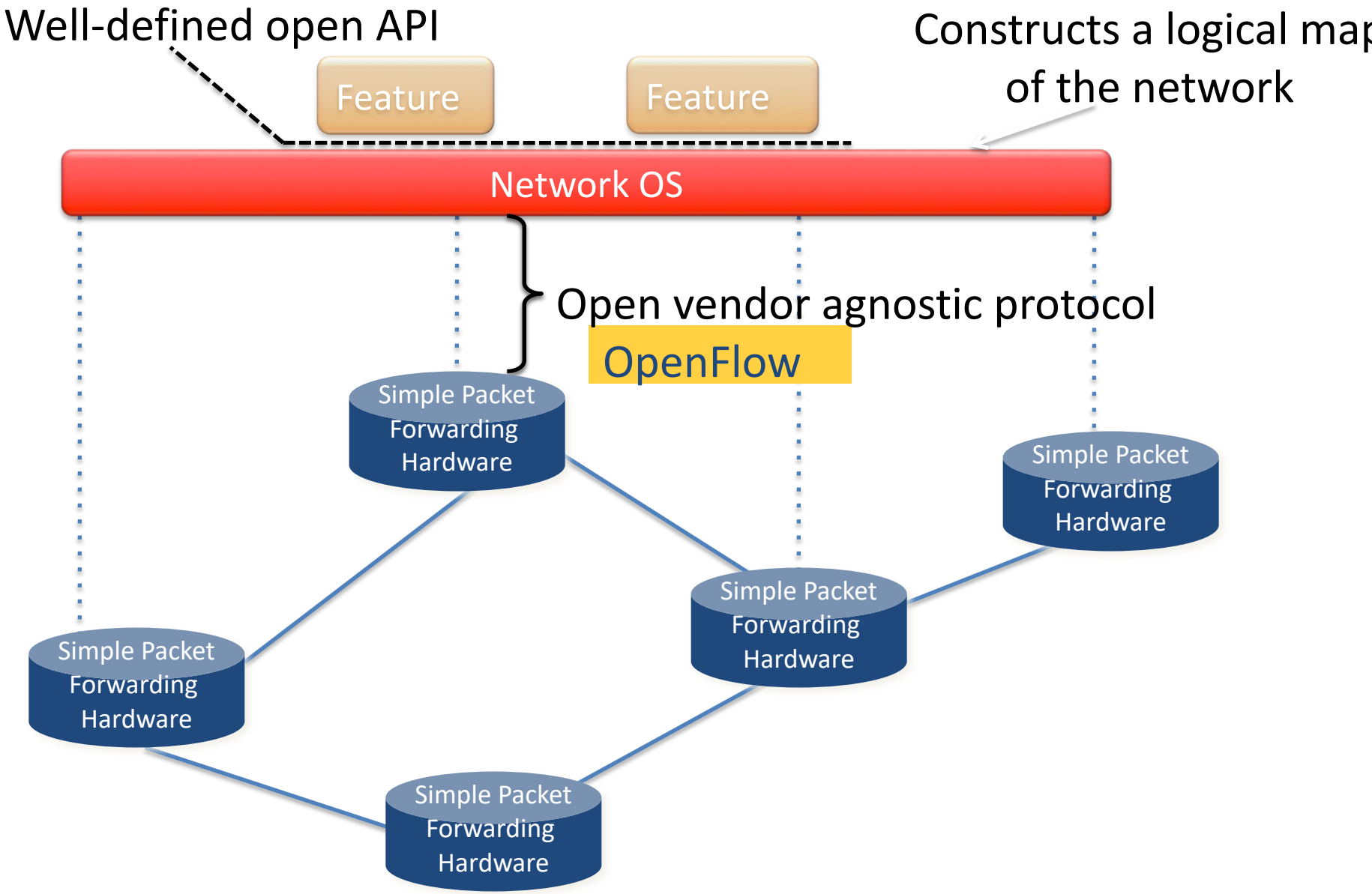
- **Network OS:** distributed system that creates a consistent, up-to-date network view- Runs on servers (controllers) in the network



Events from switches
Topology changes,
Traffic statistics,
Arriving packets

Commands to switches
(Un)install rules,
Query statistics,
Send packets

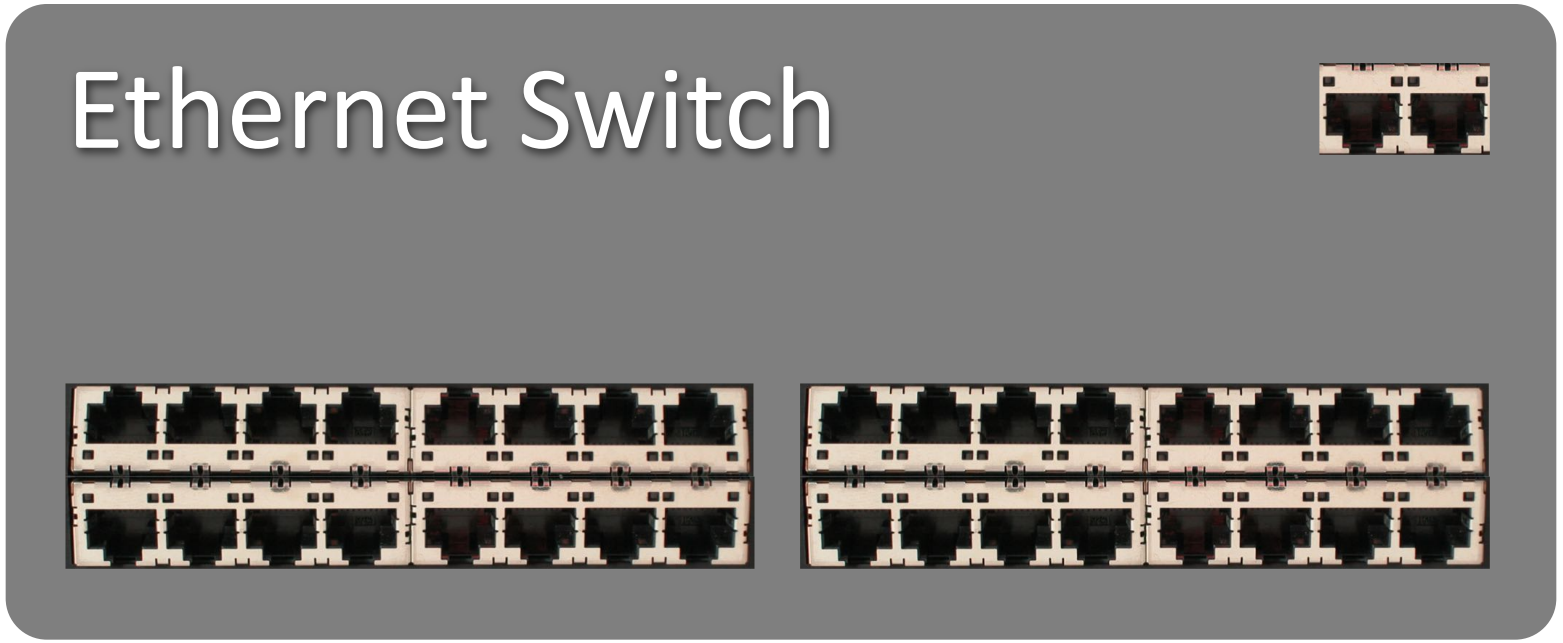
What is OpenFlow?



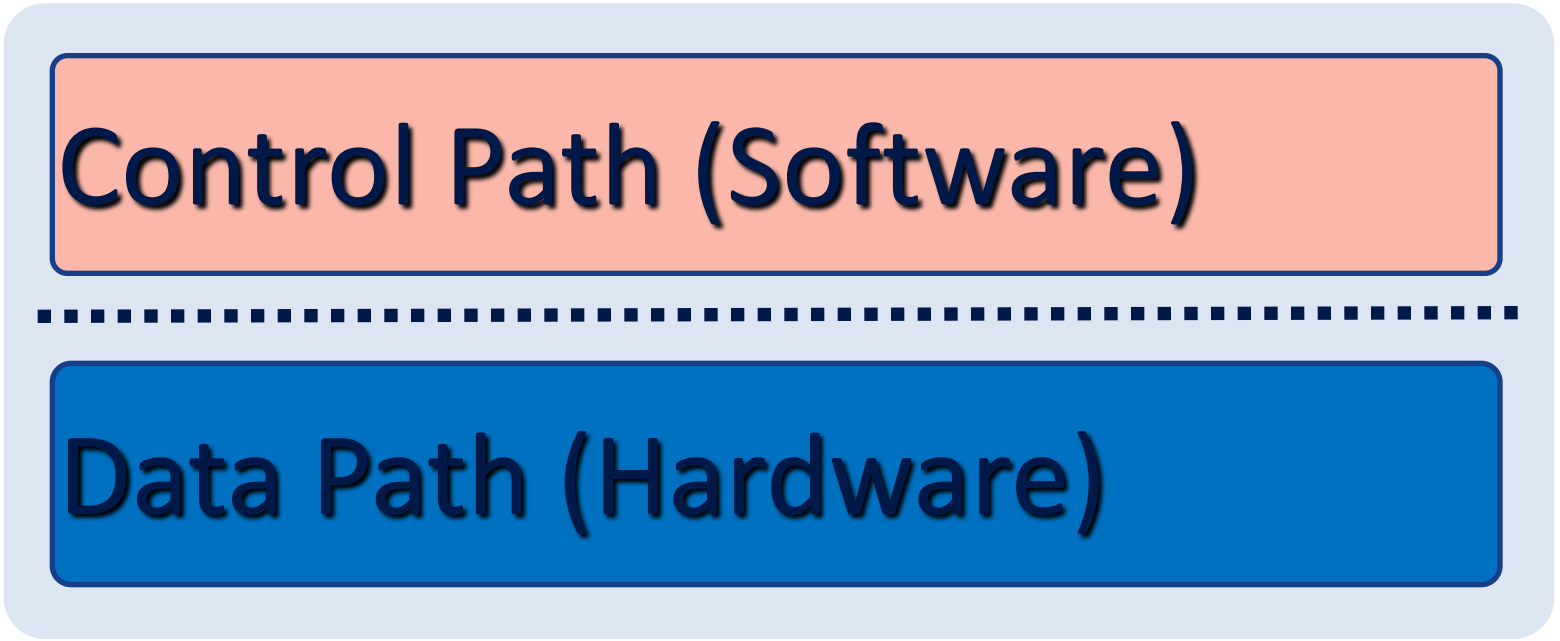
What is OpenFlow?

- Uses an open protocol to:
  - Get state information **from** forwarding elements
  - Give control directives **to** forwarding elements
- OpenFlow: **Like hardware drivers**
  - interface between switches and Network OS
  - is a protocol for remotely controlling the forwarding table of a switch or router
  - is one element of SDN

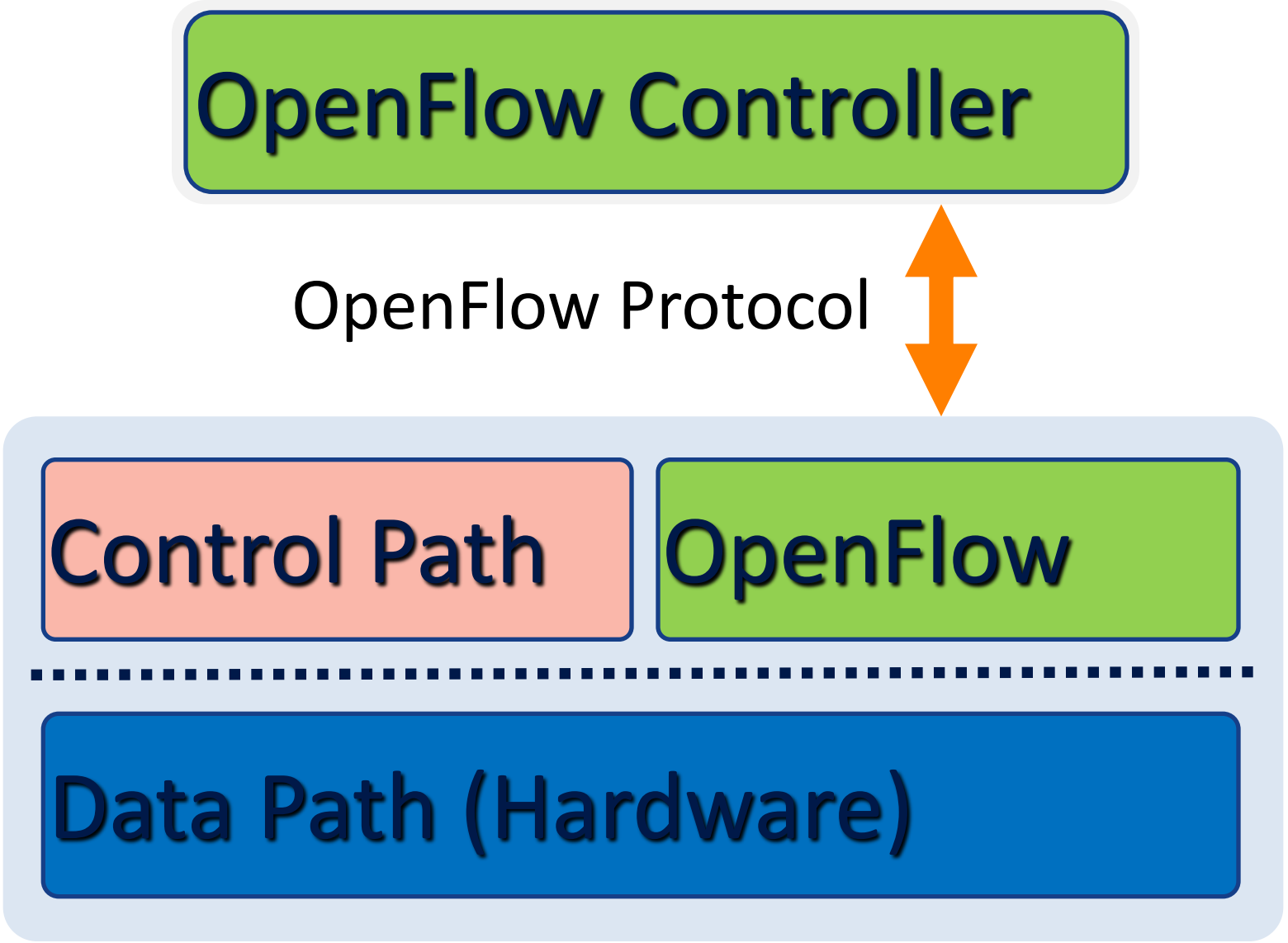
What is OpenFlow?



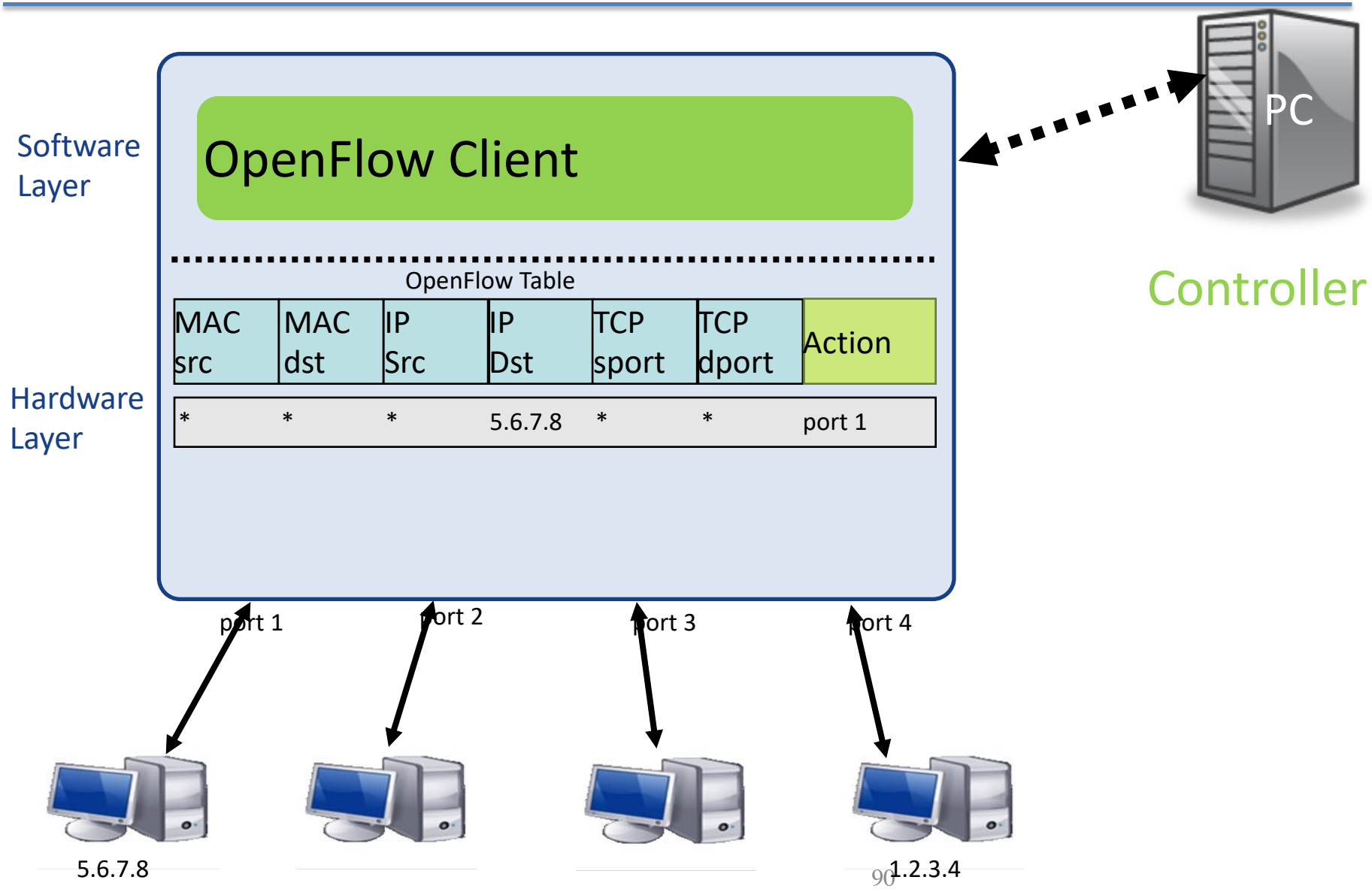
What is OpenFlow?



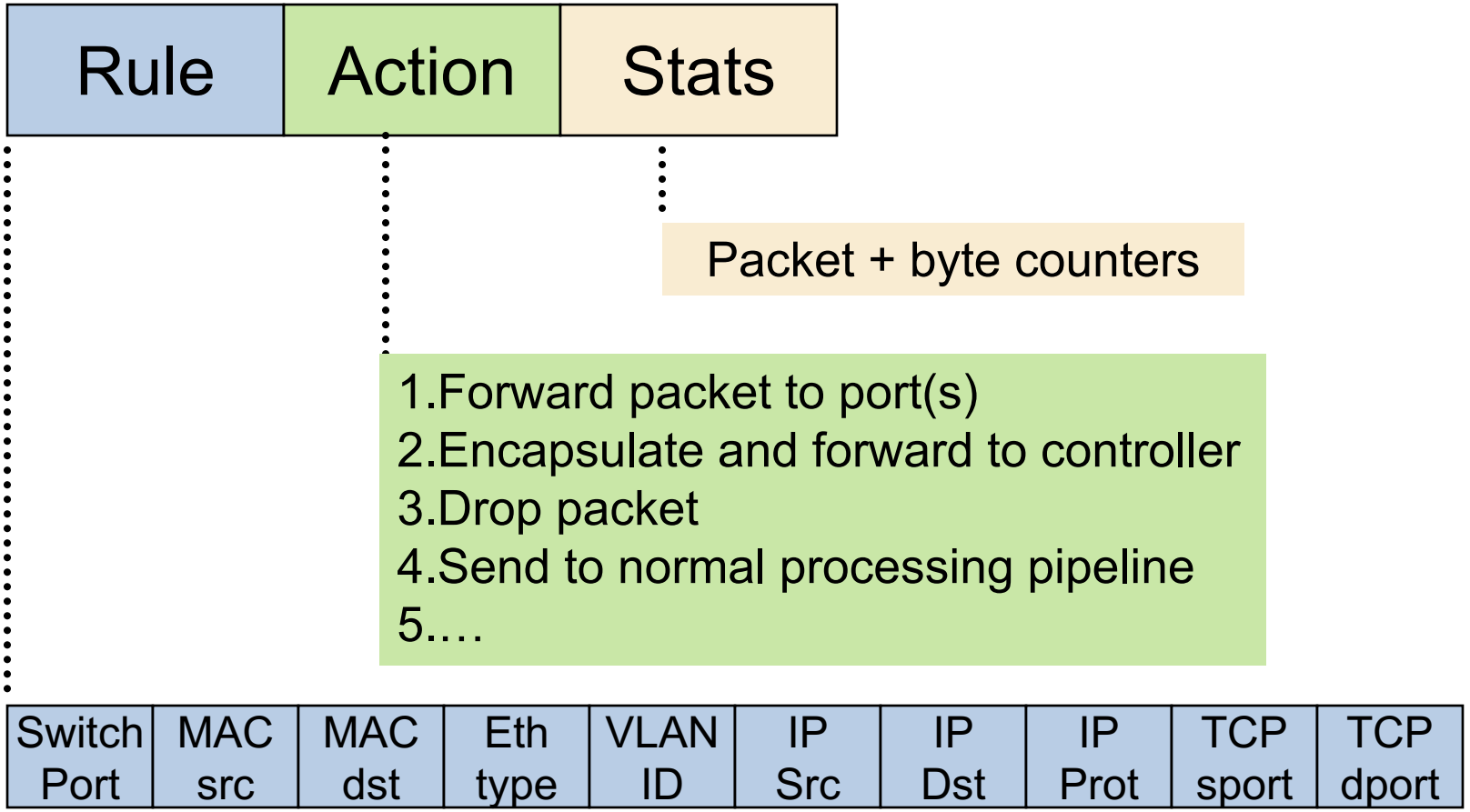
What is OpenFlow?



What is OpenFlow? OpenFlow Switching



What is OpenFlow? OpenFlow Table Entry



What is OpenFlow? OpenFlow Examples

Switching

Switch Port	MAC src	MAC dst	Eth type	VLAN ID	IP Src	IP Dst	IP Prot	TCP sport	TCP dport	Action
*	*	00:1f:..	*	*	*	*	*	*	*	port6

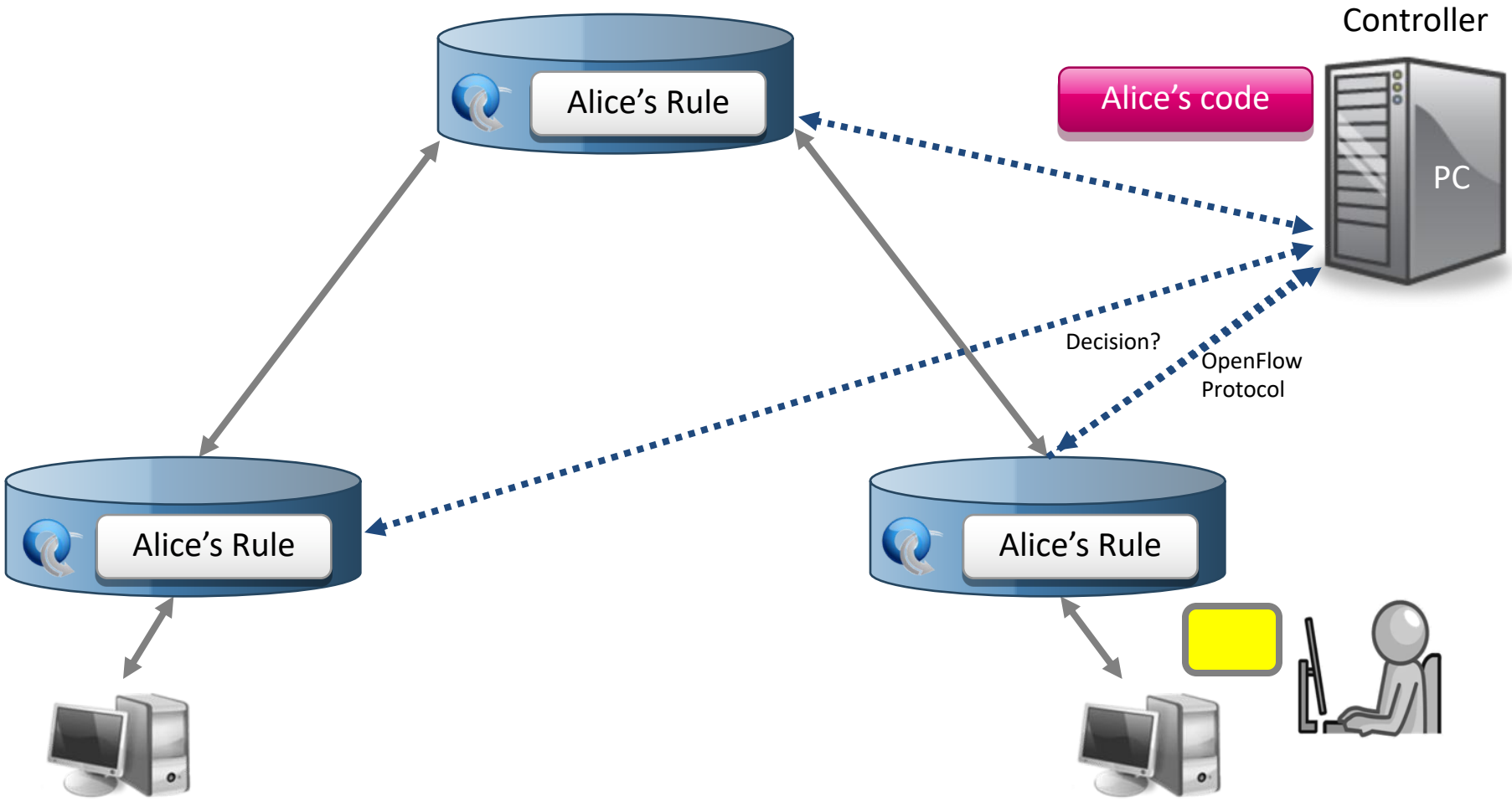
Routing

Switch Port	MAC src	MAC dst	Eth type	VLAN ID	IP Src	IP Dst	IP Prot	TCP sport	TCP dport	Action
*	*	*	*	*	*	5.6.7.8	*	*	*	port6

Firewall

Switch Port	MAC src	MAC dst	Eth type	VLAN ID	IP Src	IP Dst	IP Prot	TCP sport	TCP dport	Action
*	*	*	*	*	*	*	*	*	22	drop

What is OpenFlow? OpenFlow Usage



What is OpenFlow? OpenFlow Usage

- Simple packet-handling rules
  - Pattern: match packet header bits
  - Actions: drop, forward, modify, send to controller
  - Counters: #bytes and #packets

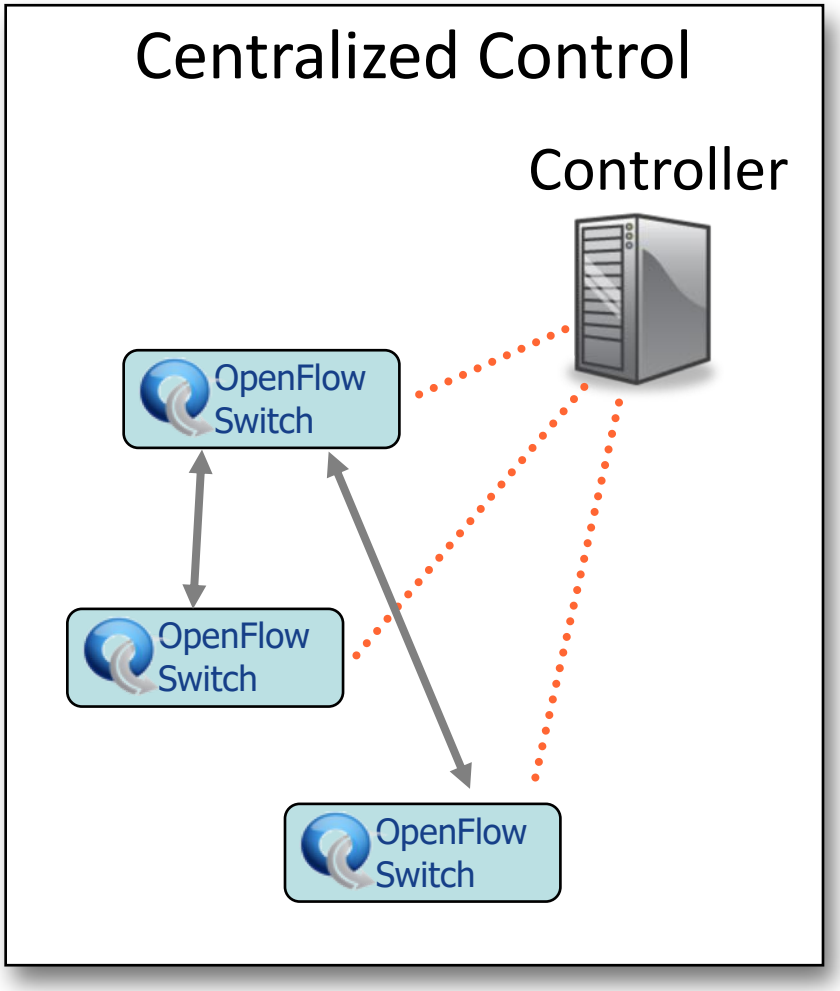
1. src=1.2.*.*, dest=3.4.5.* → drop
2. src = *.*.*.*, dest=3.4.*.* → forward(2)
3. src=10.1.2.3, dest=*.*.*.* → send to controller

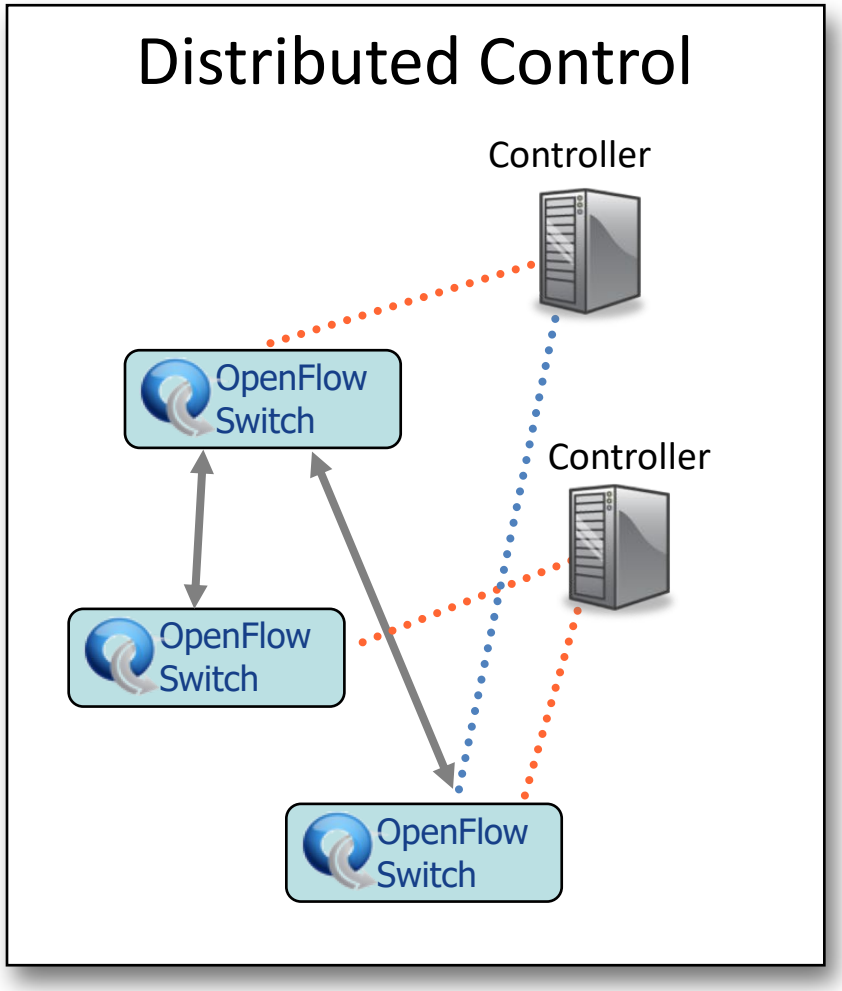
What is OpenFlow? OpenFlow Usage

Unifies Different Kinds of Boxes

- Router
  - Match: longest destination IP prefix
  - Action: forward out a link
- Switch
  - Match: destination MAC address
  - Action: forward or flood
- Firewall
  - Match: IP addresses and TCP/UDP port numbers
  - Action: permit or deny
- NAT **(Network address translation)**
  - Match: IP address and port
  - Action: rewrite address and port

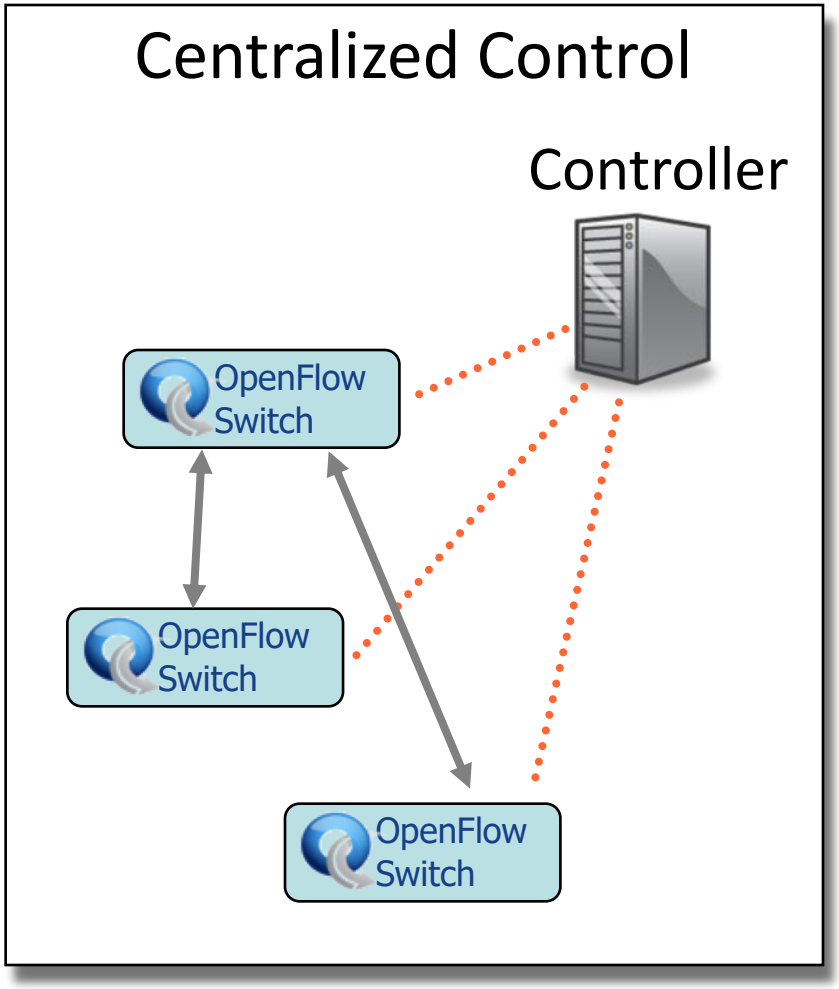
What is OpenFlow? Centralized/Distributed Control

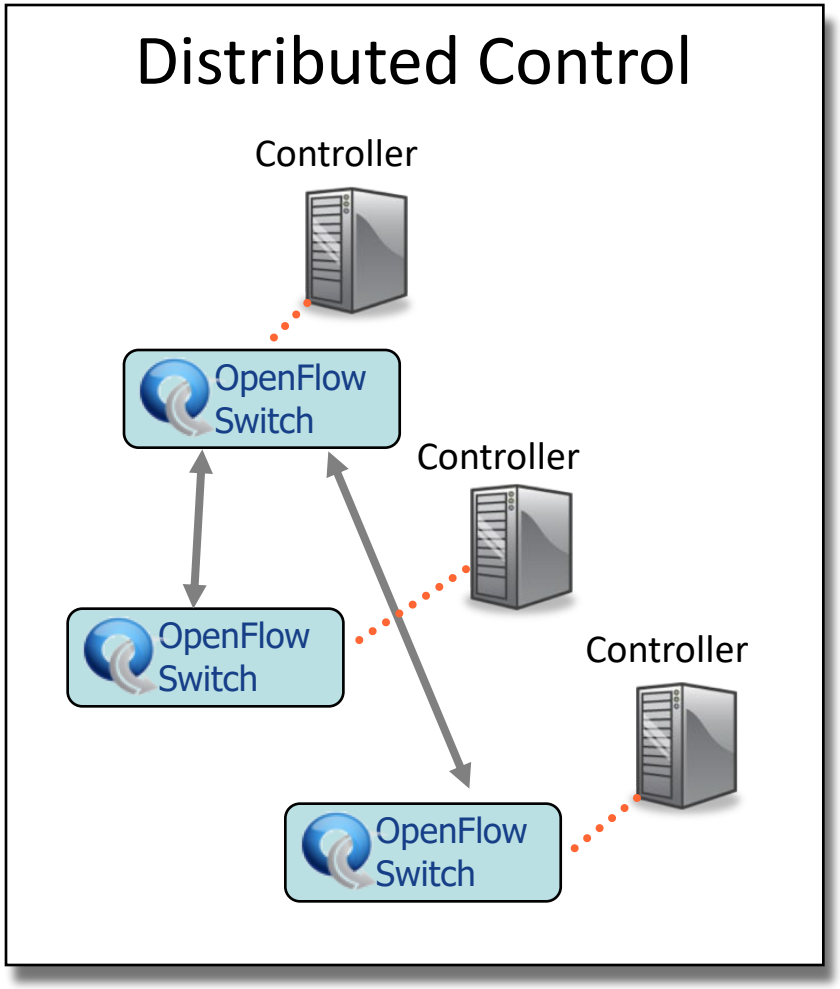




What is OpenFlow? Centralized/Distributed Control

Both models are possible with OpenFlow





What is OpenFlow?

- Open Networking Foundation
  - Google, Facebook, Microsoft, Yahoo, Verizon, Deutsche Telekom, and many other companies
- Commercial OpenFlow switches
  - HP, NEC, Quanta, Dell, IBM, Juniper, …
- Network operating systems
  - NOX, Beacon, Floodlight, Nettle, ONIX, POX, Frenetic
- Network deployments
  - Eight campuses, and two research backbone networks
  - Commercial deployments (e.g., Google backbone)

Current status of SDN

- Hardware support

Juniper MX-series

NEC IP8800

WiMax (NEC)

HP Procurve 5400

Netgear 7324

PC Engines

Pronto 3240/3290

Ciena Coredirector

More coming soon...

Current status of SDN

- Industry support
  - Google built hardware and software based on the OpenFlow protocol
  - VMware purchased Nicira for $1.26 billion in 2012
  - IBM, HP, NEC, Cisco and Juniper also are offering SDNs that may incorporate OpenFlow, but also have other elements that are specific to that vendor and their gear.

http://gigaom.com/2012/03/19/are-vendors-closing-openflow/
http://gigaom.com/2012/12/17/2012-the-year-software-defined-networking-sold-out/
http://www.extremetech.com/internet/140459-networking-is-getting-better-and-thats-partly-thanks-to-google

Future Focuses of SDN

- New policies for security
- Programmable WLANs
- The placement of controllers (amount; location; centralized/distributed)
- Debugger for SDN

Conclusions

- What is SDN?
  - A system-layered abstraction
  - Programmable, flexible, and extensible
  - Software-defined networking is still evolving
- What is OpenFlow?
  - Interface between switches and controllers
  - Enabling SDN
  - OpenFlow is being deployed in over 100 organizations world-wide

References

- www.slideshare.net/MhaeLyn/**iot**-30545508
- www.slideshare.net/CiscoIBSG/**internet-of-things**-8470978
- http://www.google.com/search?client=safari&rls=en&q=SDN+ppt&ie=UTF-8&oe=UTF-8
- https://www.cs.duke.edu/courses/spring13/.../lectures/**SDN.pptx**