Cisco Connect

The Internet of Everything

An Engineer's Perspective

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Agenda

- Defining terms
- What is the “Internet of Everything”?
  - Machine-to-Machine Networking
- Deterministic Networks
- Delay-Tolerant Networks
- Name-based and Content Centric Networking
- Where next?

Defining terms

Speaking for myself, I find the discussion of the “Internet of Everything”, or of the “Internet of Things”, confusing

Why? Concepts are discussed without defining terms, and frequently terms are used with meanings that differ from common engineering usage.

I’d like to start by defining some terms:

Internet, Internet Protocol, Best Effort, and some new terms

“The Internet”

A network of networks

- *“inter”*, meaning “between”
- *“net”*, short for “network”

Networks

- Use IPv4 and/or IPv6
- Have a common administration
- Connect to the common commercial network used world-wide

“internets”

A network of networks, disconnected from the common commercial network

- Usually special purpose networks
- *Term of art used primarily by the ITU*

It is possible to build a network of networks disconnected from the Internet

“The Internet”

A network of networks

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Networks

- Use IPv4 and/or IPv6
- Have a common administration
- Connect to the common commer cial network used world-wide

Internet Protocol (IPv4 or IPv6)

The Internetworking protocols used in the Internet.

- Also frequently used in networks not connected to the Internet

It is possible, and common, to use the Internet Protocol and not use the Internet

- *Some networks use other, more specialized, protocols*

Reliable Network

A network that, given a packet to s end, delivered it or died trying

- X.25 was the prototypical reliable network

Arguably, a network that needed no transport layer

Best Effort Network

A network that delivers packets from end to end, except that

- It might delay them
- It might lose them
- It might duplicate them
- It might reorder them

Fundamental paradigm:

- “Handing my data to the enem y and hoping for a specific service”

We are adding to that taxonomy…

What does the Internet connect?

Most Internet applications connect

- *People to people*, such as in Instant Messaging, electronic mail, or Voice/IP
- *People to content*, such as the world wide web, Bit Torrent, or Internet video (YouTube etc.)

What is the “Internet of Everything”?

Machine-to-Machine Networking

- “internet”, not necessarily “The Internet”
- Usually using networking for telemetry or control

Focuses on connectivity to accomplish specific tasks

- Industrial automation (may be Ethernet or IP)
- Smart Grid (may be IPv6, IPv4, ANSI C12, or others)
- Building Automation (IEC 14908 etc.)
- Automotive communications (IPv6 or others)

Some new concepts in network design and application

Telemetry and Control: For example, the Smart Grid and Home Health Care

The Bellagio Fountains

Individual water nozzles controlled using Echelon (IEC 14908) controllers

Protocol used for synchronization of independent program elements

“everybody do step 1”
“everybody do step 2”
…

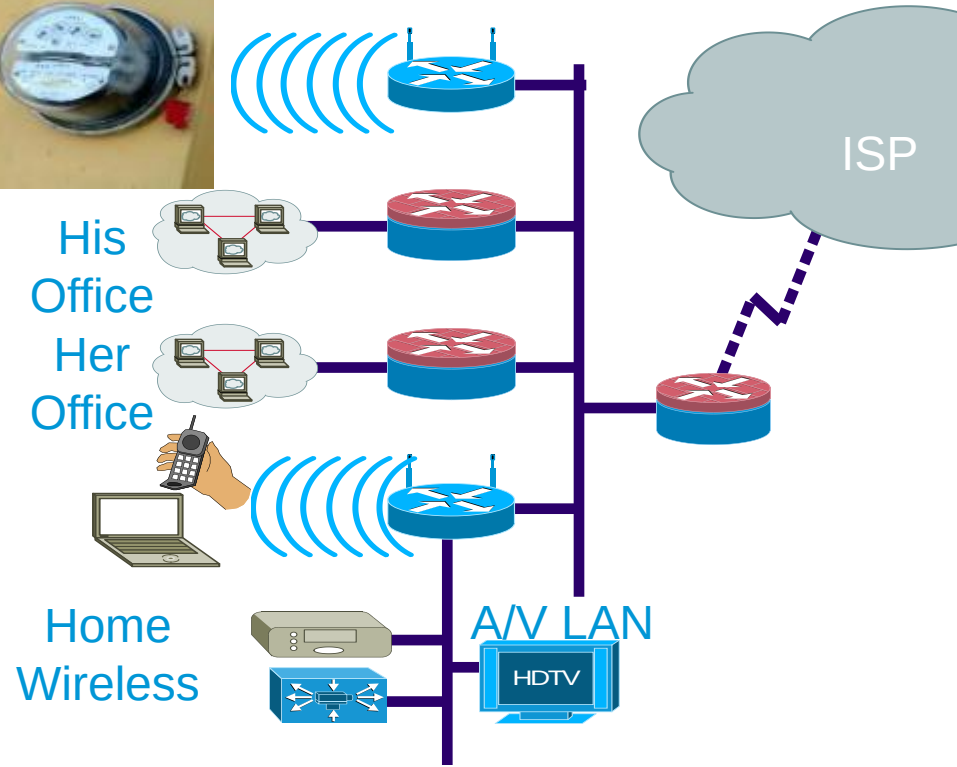
Residential Network and Home Area Network Interaction

Imagine a high end home network:

- Audio/Video
- Wireless
- Telecommuting
- Home Area Network

What is the HAN?

- Network connecting sensors in the home
- Communications with utilities
- Services to residents



Related to sensor networks for health…

- Infrared
- Motion sensors
- EKG
- Pedometers
- …

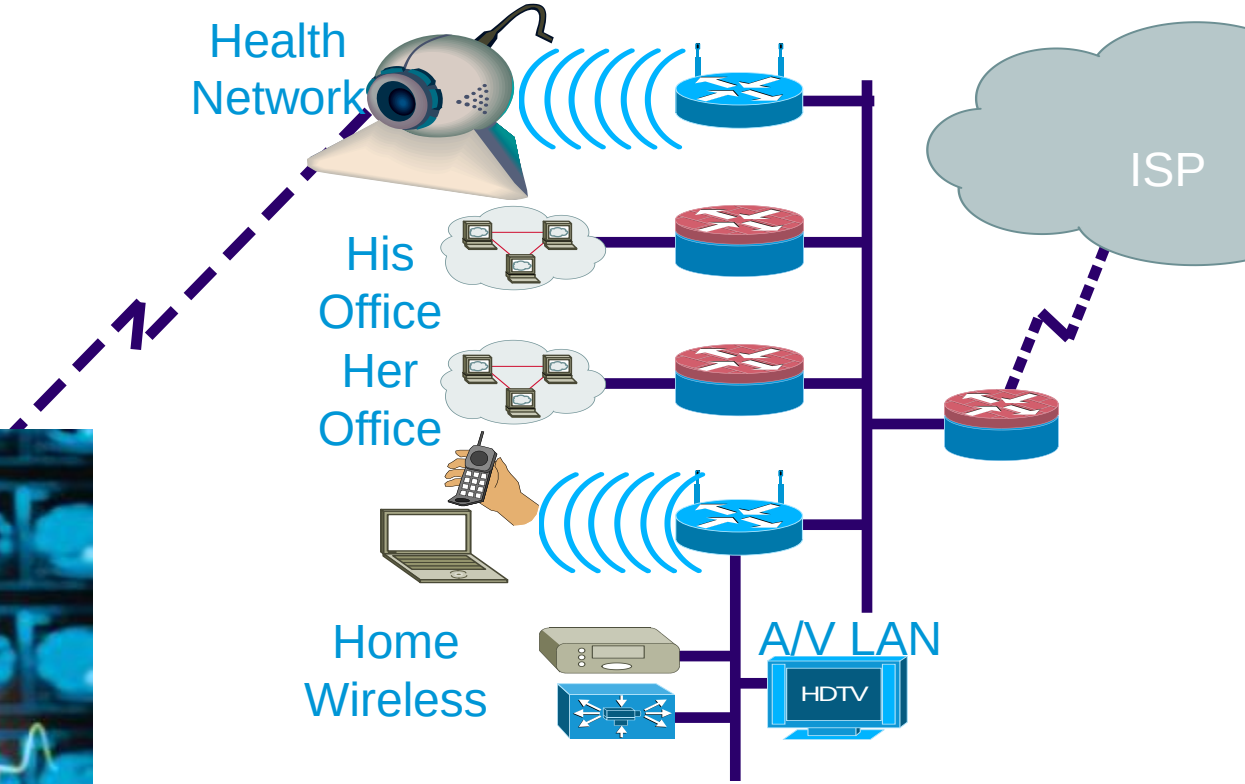
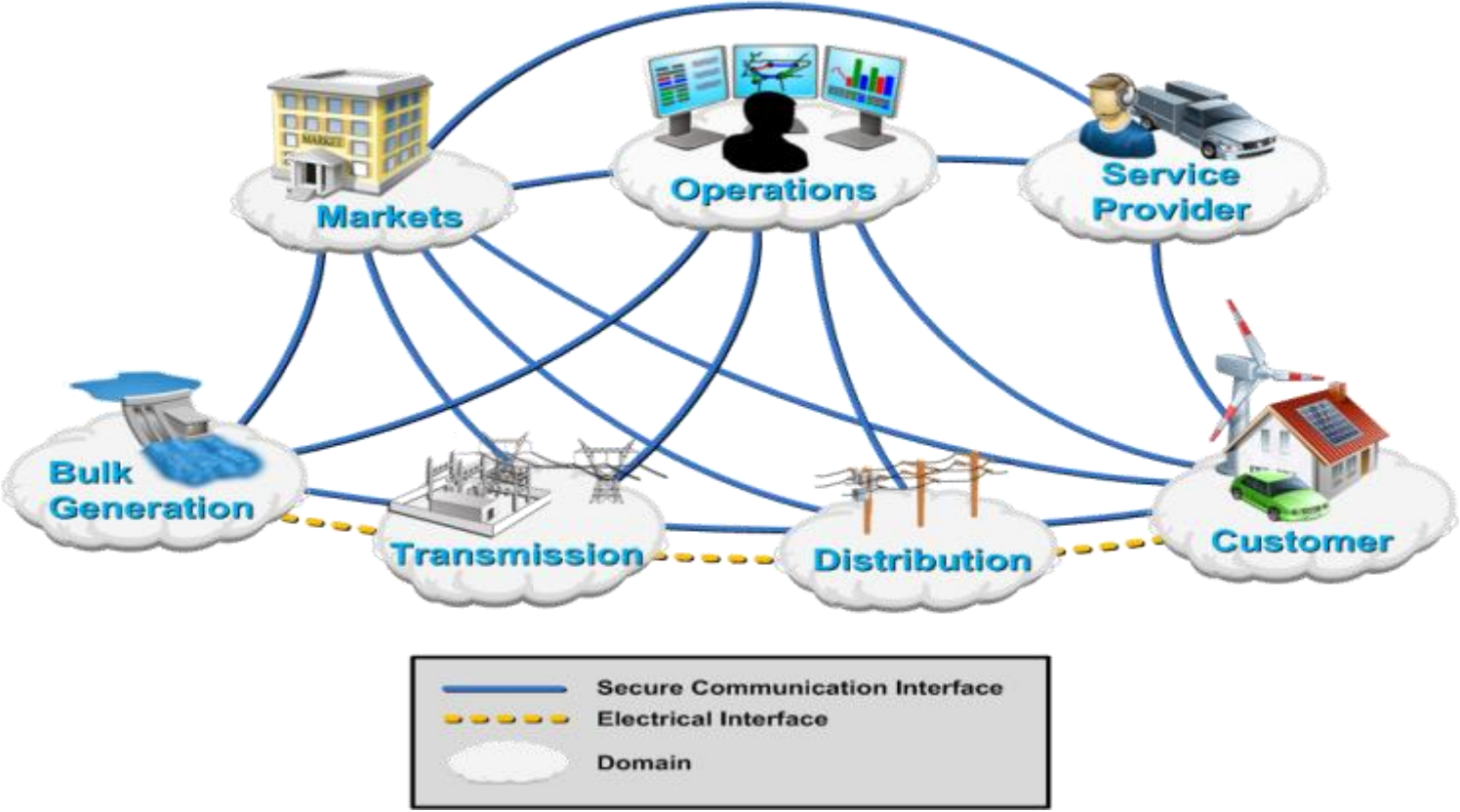


Figure 4: Domain Decomposition

A brief overview of the Smart Grid

Conceptual model from a business perspective



“ ...the Network should enable an application in a particular domain to communicate with an application in any other domain in the information network, with proper management control over who and where applications can be interconnected.”

NIST Roadmap, Version 1.0, September 2009

What kinds of security mechanisms?

Communication Layer	Type of control	Example
Data Content	End to end integrity in message-based exchange	W3C XML Signature
Application Layer	Application to application authentication, authorization, encryption	TLS, HTTPS, DKIM, S/MIME, SSH
Network Layer	System-to-system authentication, authorization, encryption	IPsec ESP
Physical/Link Layer	Limited Membership	SSID, IEEE 802.1X with EAP-TLS

Deterministic Networks IEEE 802.1aq

What does “deterministic network” mean?

It means that in this type of network, **end to end delay is**, to the extent this is possible, **fixed**.

- *It does not mean that loss cannot happen.* End to end reliability is not built into the network itself.
- *It does not mean that mean delay is reduced;* it may be increased end to end.
- It does mean that variation in delay and congestive loss are removed from the equation via scheduling.

It also means that **transmission** for this class of traffic **is time-triggered**

The application using a deterministic service may only send at specified times, and knows that the message will be delivered within a specified interval

Coexistence of deterministic and best effort services

- Best Effort services often divide traffic into classes using the Differentiated Services model
  - Traffic in various service classes get different treatment – priority scheduling, rate control, etc..
- How IEEE 802.1aq might do it:
  - Set a service class aside for deterministic traffic,
  - Give the controller assurance that no best effort traffic will use the network at specific times
  - Let the controller program end station applications accordingly

Impact

For deterministic applications

- We have now built the extreme case of a Slotted ALOHA network
- Each deterministic sender has one slot, which it might or might not use – n o statistical multiplexing
- Since there is no contention, very predictable
- Since there is no contention, persistent under-use

For competing best effort traffic,

- Interconnecting links appear to have less capacity
- Best Effort traffic encounters jitter comparable to the size and distribution of “deterministic intervals”

How might determinism be used?

Robotics

- Right now, we generally put robotic applications needing determinism on their own networks
- Which is somewhat inefficient

Determinism is important when doing something that requires precision and ef ficiency

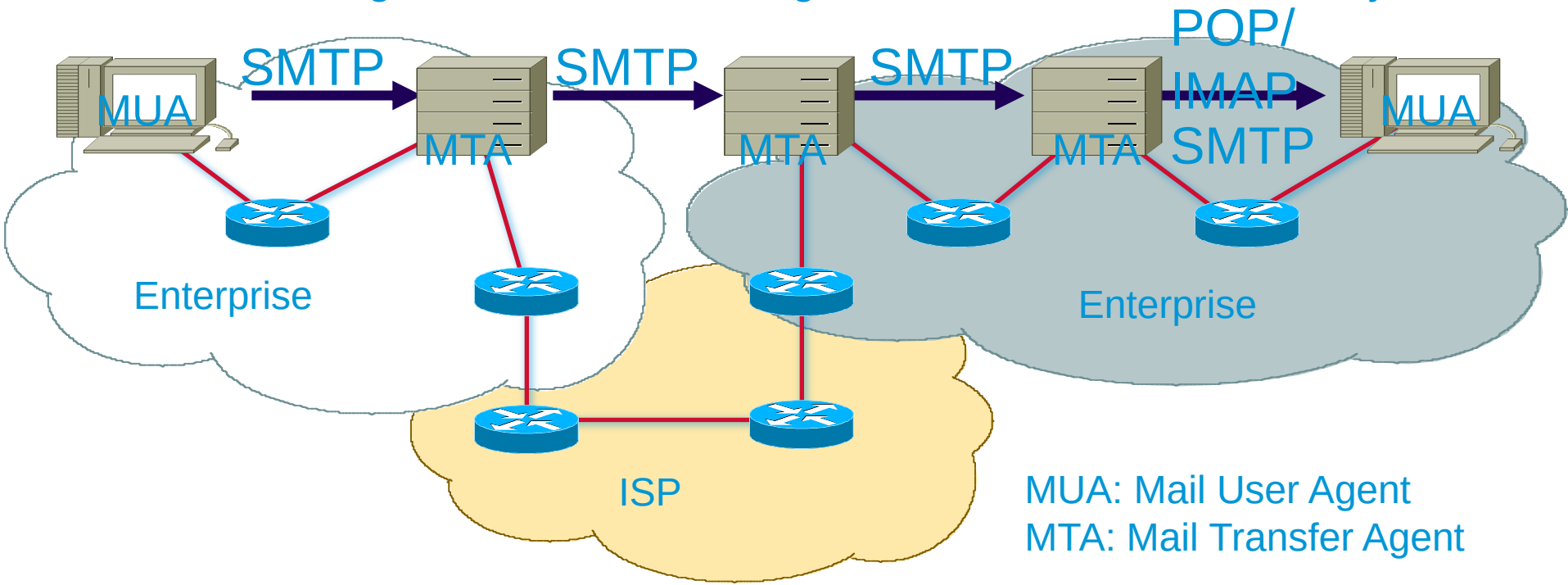
Delay-Tolerant Networks

When you can’t assume sender and receiver are online at the same time

The canonical delay-tolerant application: Electronic Mail

MUA-MTA or MTA-MTA service is a typical Internet file transfer

End to end, though, communication might take minutes, hours, or days



MUA: Mail User Agent

MTA: Mail Transfer Agent

Tsinghua Experiment measuring pollution using a Delay-Tolerant Network

Fitted taxis with sensors, GPS and Wi-Fi

When it stops, take a sample, timestamp, analyze, and store it for some interval

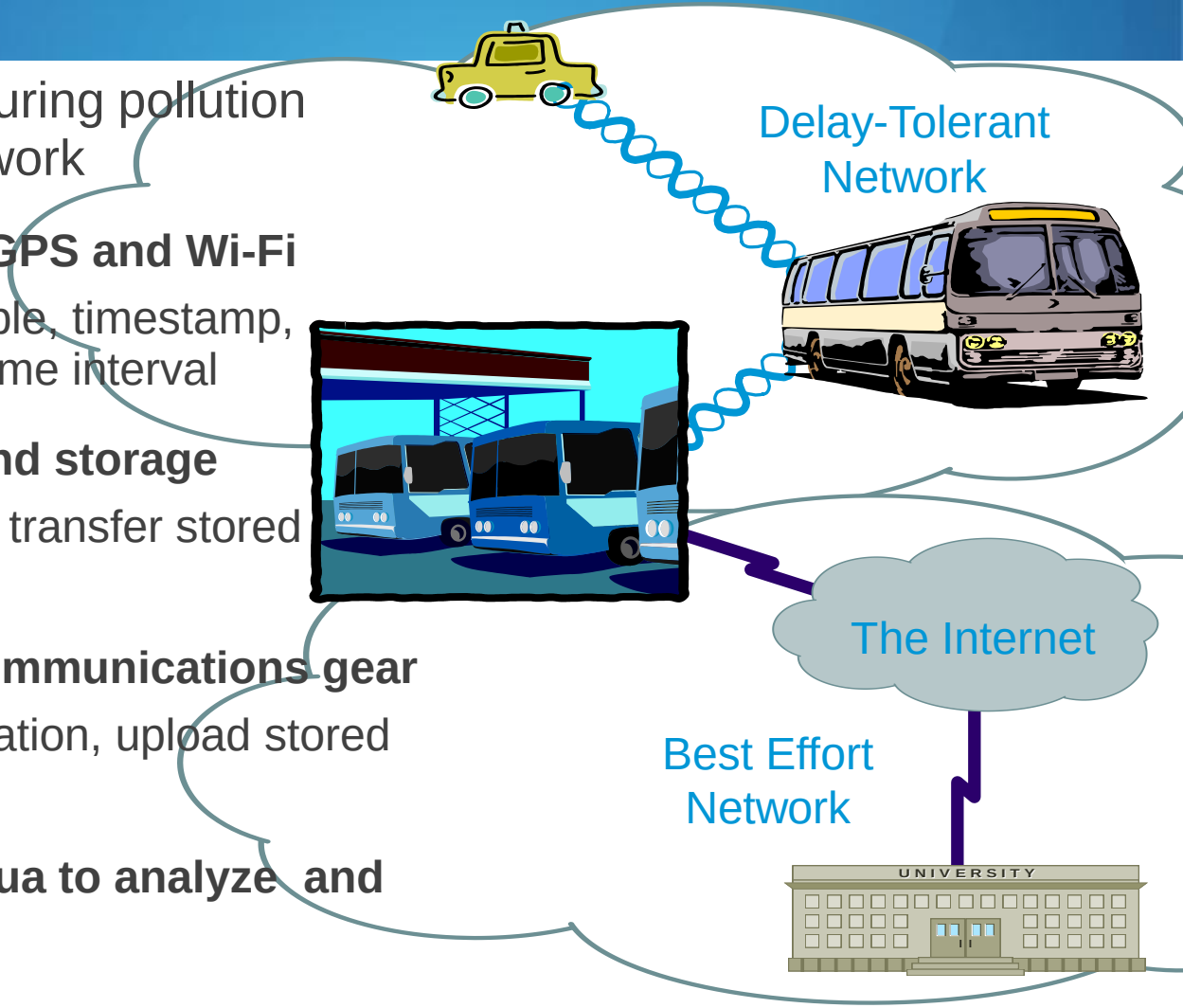
Fitted busses with Wi-Fi and storage

When a taxi passes a bus, transfer stored information to the bus

Fitted bus stations with communications gear

When a bus arrives at a station, upload stored data to Tsinghua

Built application at Tsinghua to analyze and interpret the data



How about a Bluetooth light switch?

Theory:

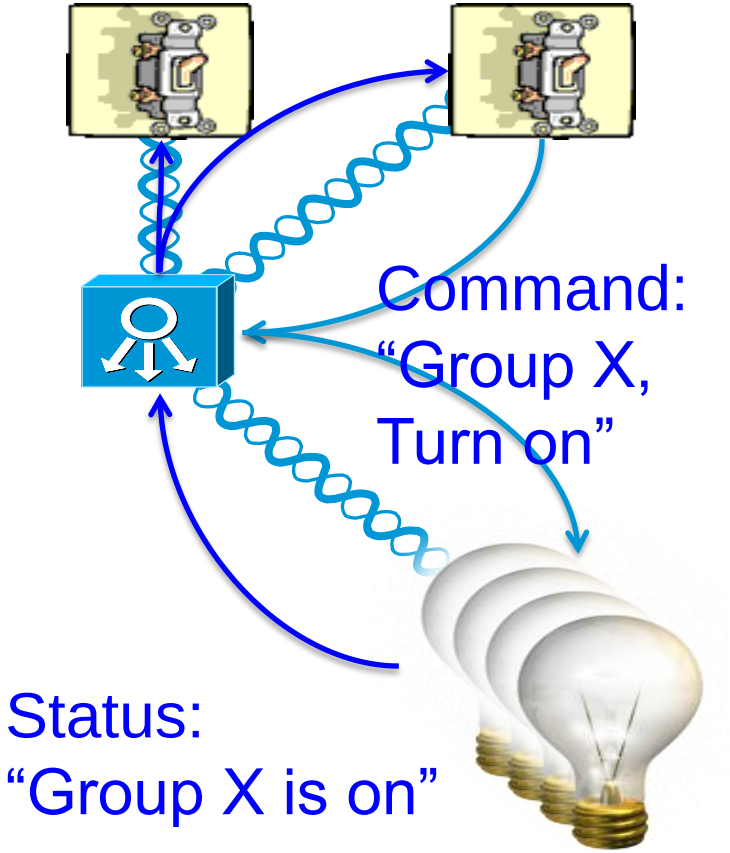
- A light switch can tell a light to turn on and off with a message

Issue:

- It's usually "light bulbs"
- What if there is more than one switch?
- Power – battery operated, needs to last for many years

When to send message?

- When the recipient is listening!



Name-based and Content Centric Networks

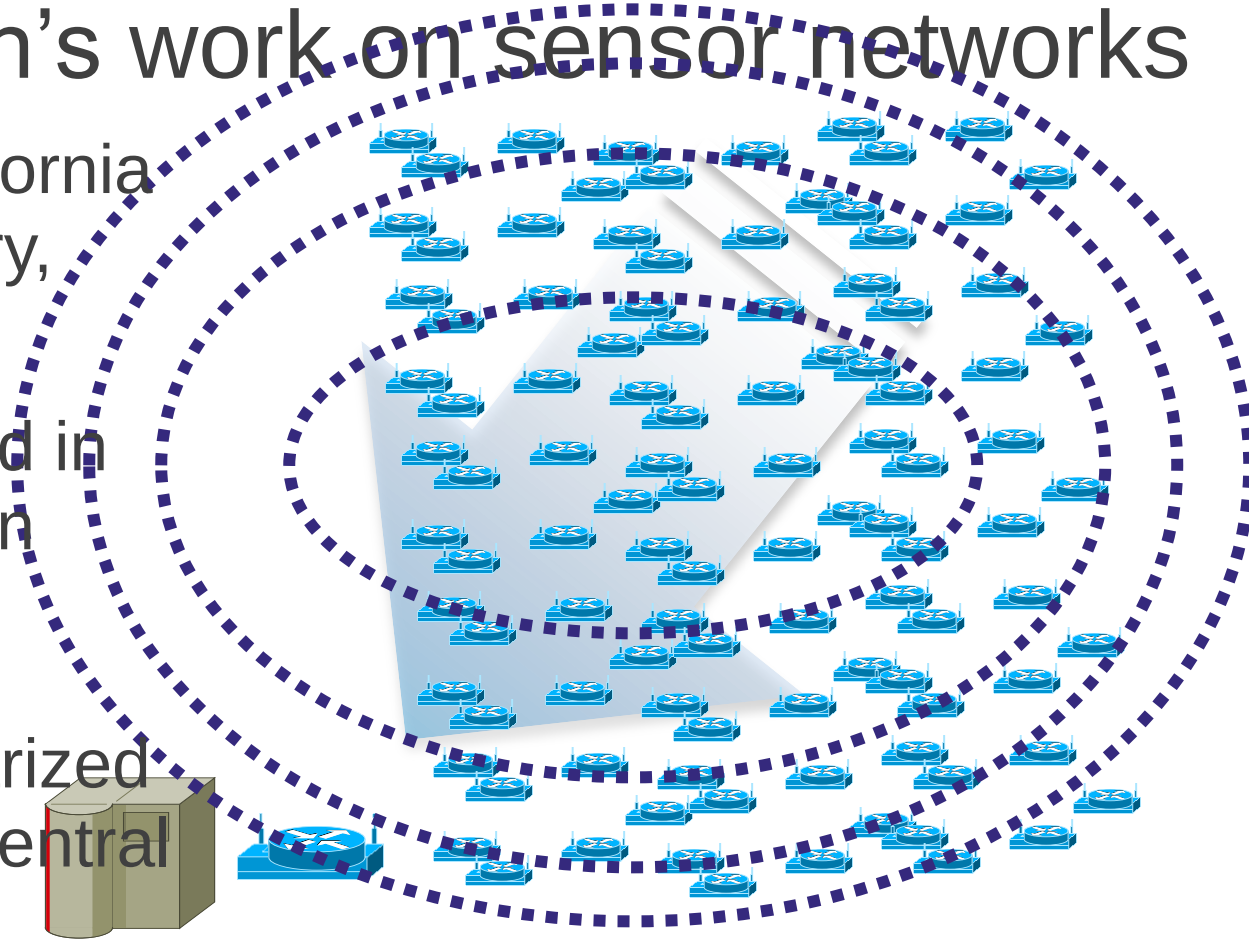
Deborah Estrin's work on sensor networks

Working with California Division of Forestry, UCLA, and UCSB

Networks deployed in random distribution

Low power

Delivering summarized sensor data to a central site

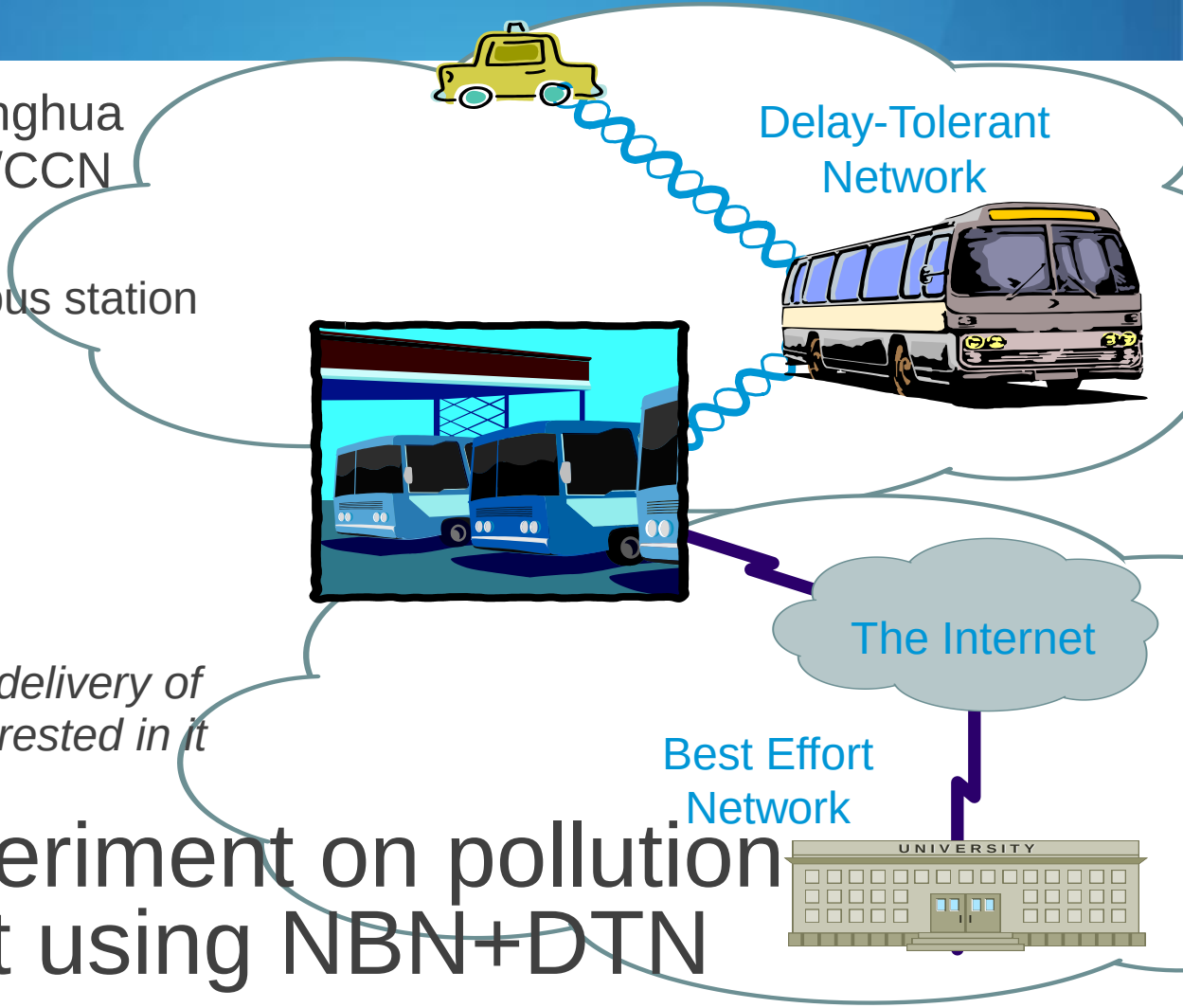


Key concepts in Content Based Networks

- Only deliver wanted data
  - Sensors generate signed, identified data
  - Sensors store that data in the network
  - Consumers express interest in that data
  - Data wanders toward consumers because *they want it*, not because *they asked for it* or *the sensor sent it*
- Issues
  - Scalability is the biggest issue
  - Many-to-few or many-to-one applications
    - Not everyone is a consumer

Another view on the Tsinghua experiment from a NBN/CCN angle:

- FTP/TCP/IP useful bus station to Tsinghua
- TCP/IP useful
  - taxi-to-bus and
  - bus-to-station,
  - room for optimization
- *The key thing is the delivery of content to those interested in it*



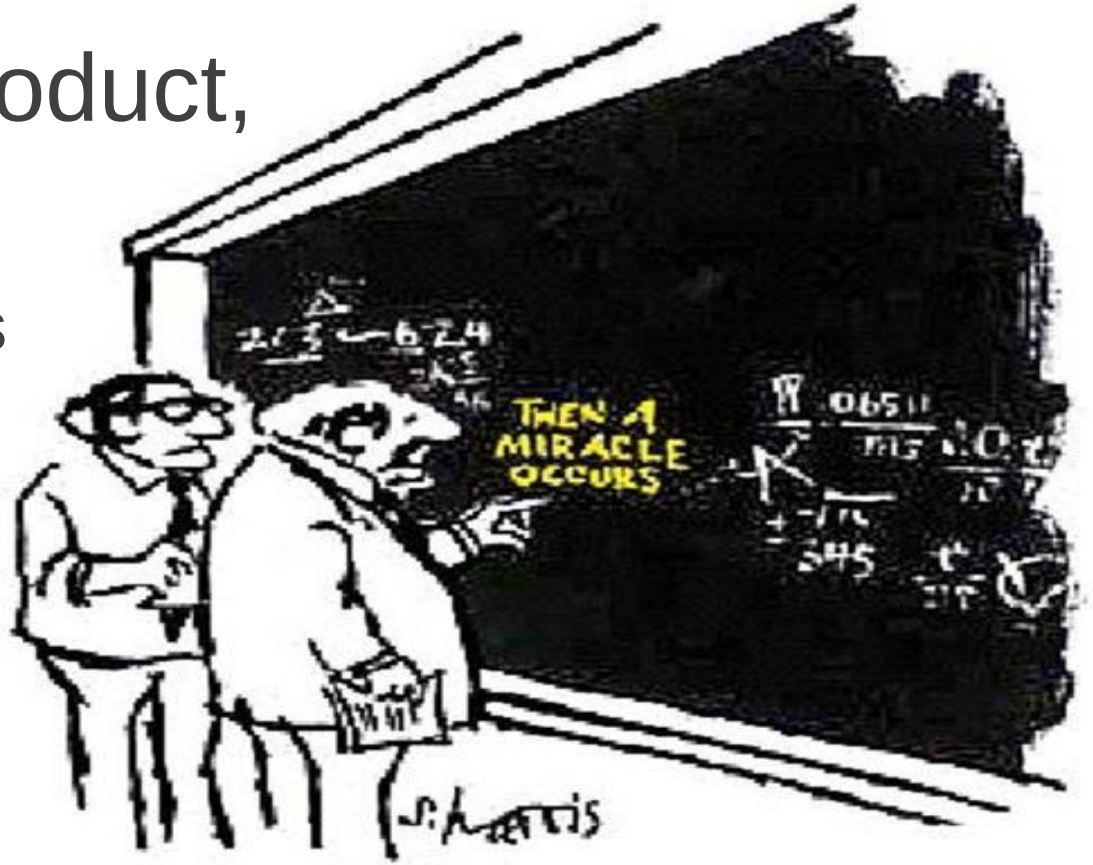
Tsinghua experiment on pollution measurement using NBN+DTN

Where next?

Some of this is product, some is research

There are a few places that still need work

- Scaling approaches of some IoE technologies not proven in large networks
- We have some things to learn yet



"I THINK YOU SHOULD BE MORE EXPLICIT HERE IN STEP TWO."

Thank you.
감사합니다