ECEN 5053-002

Developing the Industrial Internet of Things

Week 4 - Lecture

Networks, Wireless Protocols

Dave Sluiter - Spring 2018

Learning Outcomes

- Learn the names of the top network and ISP providers
- Understanding basic networking concepts
- Grasp the basics of Network Functions Virtualization (NVF)
- Grasp the basics of Software Defined Networks (SDF)
- Learn the names and basic information on the leading long-range and short-range wireless protocols

Material

- Networks
- Wireless Communication Protocols

Networks

Network Topics

- Networks
  - Survey of leading providers
  - Network terminology and topologies
  - Network Functions Virtualization (NFV)
  - Software Defined Networks (SDF)

United States Internet Service Providers

- AT&T
- Verizon
- Comcast
- Time Warner
- Charter
- Century Link
- CableVision
- Cox
- SuddenLink
- CableOne
- Frontier Communications

European Internet Service Providers

- Vodafone
- Tele Columbus
- TIM
- Infostrada
- Ono
- Altibox
- Virgin Media

India Internet Service Providers

- BSNL (National Internet Backbone)
- Excel Broadband
- Tata Teleservices
- Hathaway
- YOU Broadband
- ACT Broadband
- Beam Fiber
- Micronova Network Solutions

China Internet Service Providers

- China Mobil
- China Netcom
- China Telecom

Top World Internet Service Providers

- South Korea: HelloVision
- Japan: NTT East
- Hong Kong: Hong Kong Broadband Network
- France: Orange
- Latvia: Balti-Com
- Romania: Madnet
- Ireland: Vodafone
- Czech Republic: UPC

Source: http://uswww.rediff.com

Top World Players in Cellular IoT Market

1 Qualcomm Inc. (U.S.),
2 Gemalto N.V. (Netherlands),
3 Sierra Wireless (Canada),
4 U-Blox Holding AG (Switzerland),
5 MediaTek Inc. (Taiwan),
6 Telit Communications PLC (U.K.),
7 ZTE Corporation (China),
8 Mistbase (Sweden),
9 Sequans Communications (France)
10 CommSolid GmbH (Germany)

Source: Markets and Markets

Network Terminology

- **Store and Forward Switching**
  - Pre-dates computers, point-to-point teleprinter equipment
  - Stored on punched paper tape
  - Humans read the address
  - Then forwarded to recipient
- Modern use: An entire packet is received, checked for errors and then forwarded
  - Used in delay-tolerant applications or where intermittent communication is acceptable
  - Not applicable to real-time systems

Network Terminology (con't)

- **Cut Through Switching**
  - A switch starts forwarding a packet once the destination address is received
  - If the end CRC check fails, a marker/symbol at the end of the packet is set to indicate the failure.
  - Greatly reduces latency
  - Applicable to real-time systems

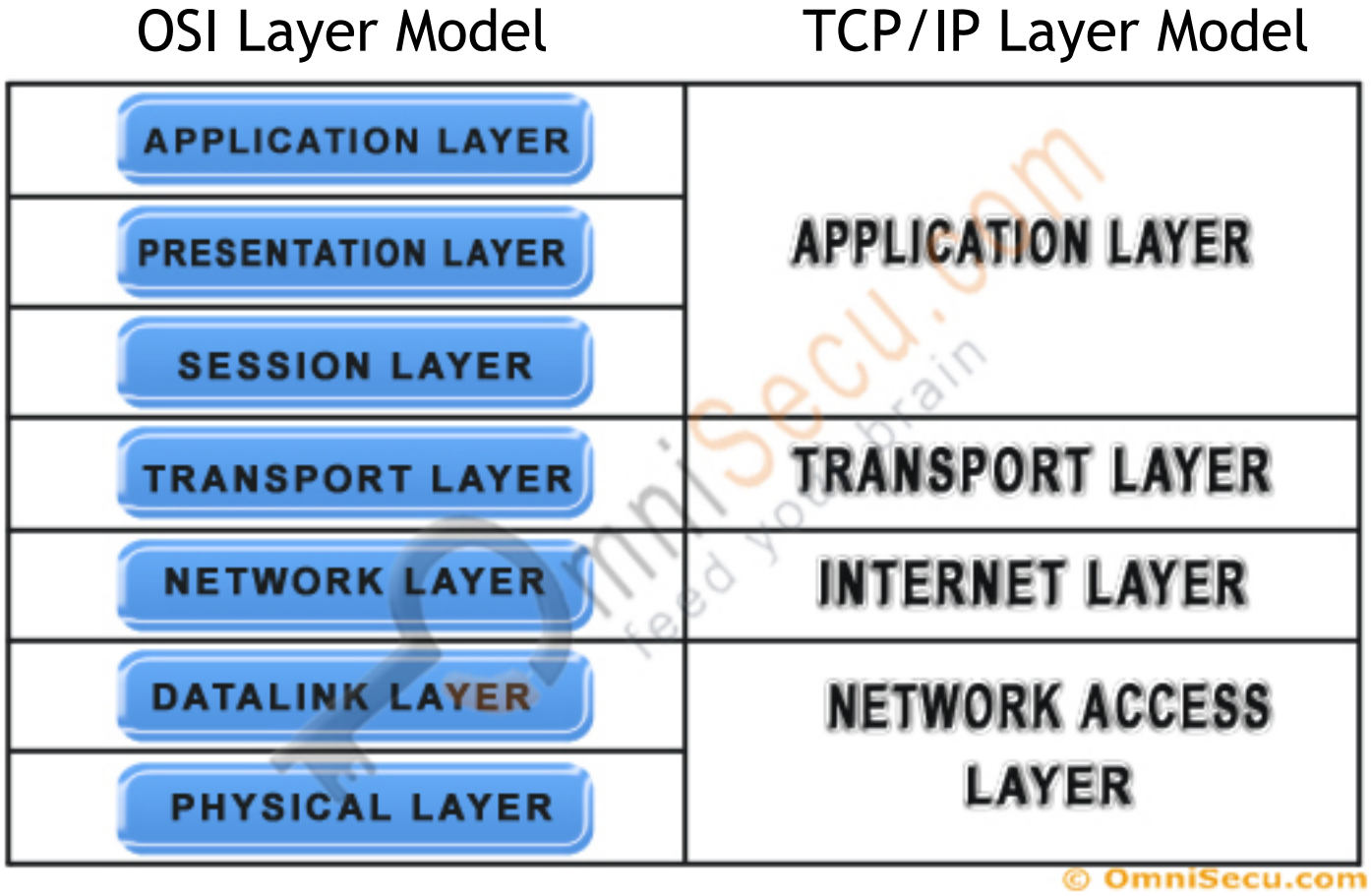
Network Terminology (con't)

- DPI: Deep Packet Inspection
- TCP/IP Network layer model:
  - Layer 1: Network Access layer: Defines how data is physically sent.
  - Layer 2: Internet layer: Packs data into packets known as datagrams. Contains source and destination IP address. This layer is also responsible for routing.
  - Layer 3: Transport layer: Enables devices at the source and destination to carry on a conversation. Defines the level of service and connection status.
  - Layer 4: Application layer: Provides APIs and protocols to application programs.

Network Terminology (con't)

- MIMO
  - Multiple Input Multiple Output
- M2M
  - Machine-to-machine communication, non-TCP/IP based (example: Bluetooth)
- IoT or IIoT
  - TCP/IP based communication

Network Terminology (con't)



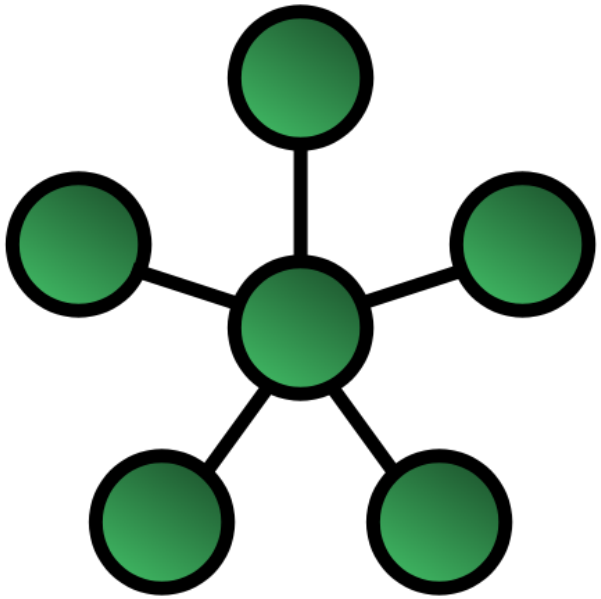
Source: http://www.omnisecu.com

Network Toplogies

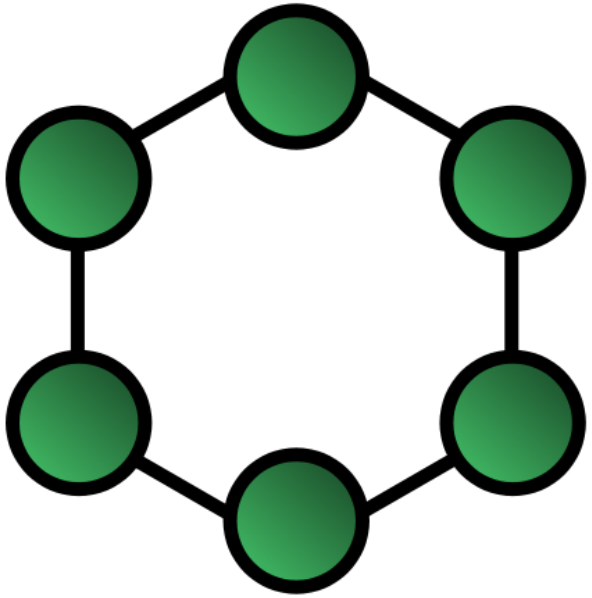
- **Physical topology** refers to the cabling (or wireless connections), node locations and interconnections between nodes. The physical topology is driven by the level of control, fault tolerance and cost required.
- **Logical topology** refers to the way data is passed through a network from one node to the next.

Network Topology Examples

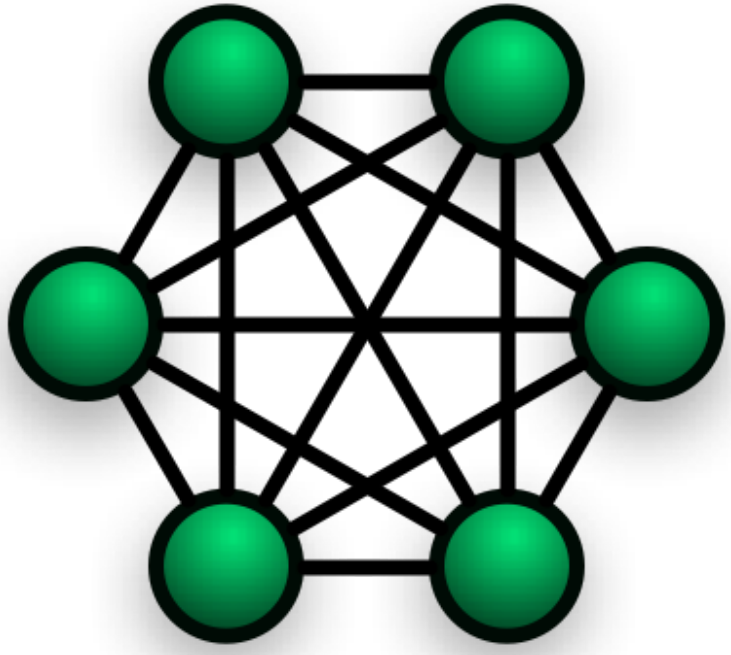
Star



Ring



Full-mesh

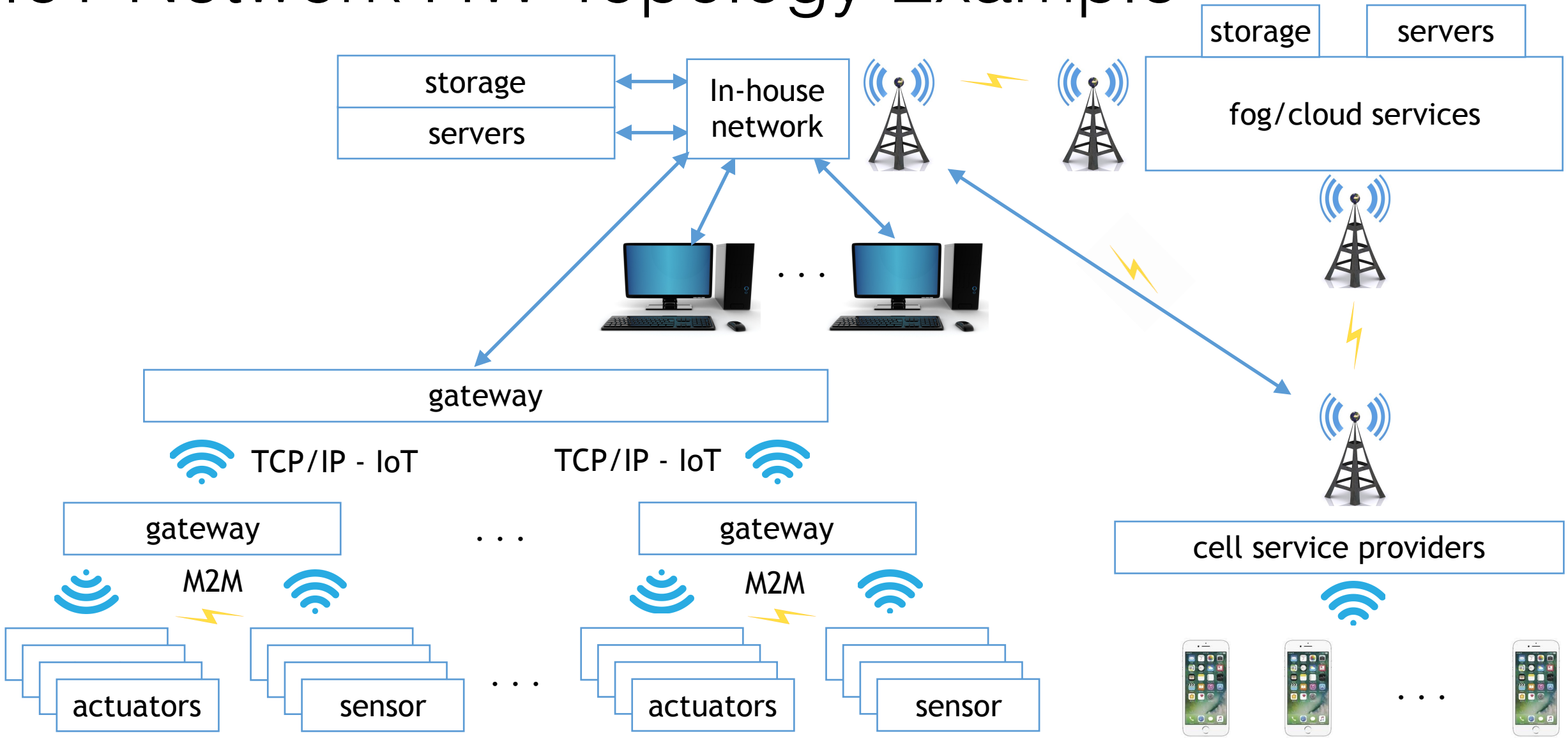


Source: https://en.wikipedia.org/wiki/Network_topology

Network Topology Examples

- Token ring is physically a star topology, but operates as a ring
- Most of our home Wifi networks are physically and logically a star:
  - Hub/Router/Gateway
    - Device 1 (Cell Phone)
    - Device 2 (Computer)
    - Device …
    - Device N (XBox)

IIoT Network HW Topology Example



Network Functions Virtualization

- https://www.youtube.com/watch?v=SIKxuFsx1l0
- https://www.youtube.com/watch?v=pxQAL-gxiNk
- https://www.youtube.com/watch?v=imkJOobsfxE
- NFV allows network operators to dynamically place (or move) networking capability as usage demands change.

Network Functions Virtualization

Network Functions Virtualization

Network Functions Virtualization

Software Defined Networks

- https://www.youtube.com/watch?v=lPL_oQT9tmc
- https://www.youtube.com/watch?v=vohyzHE3BpU
- SDN typically divides network functions into data and control and provides the mechanisms to dynamically determine how network traffic flows through a network.

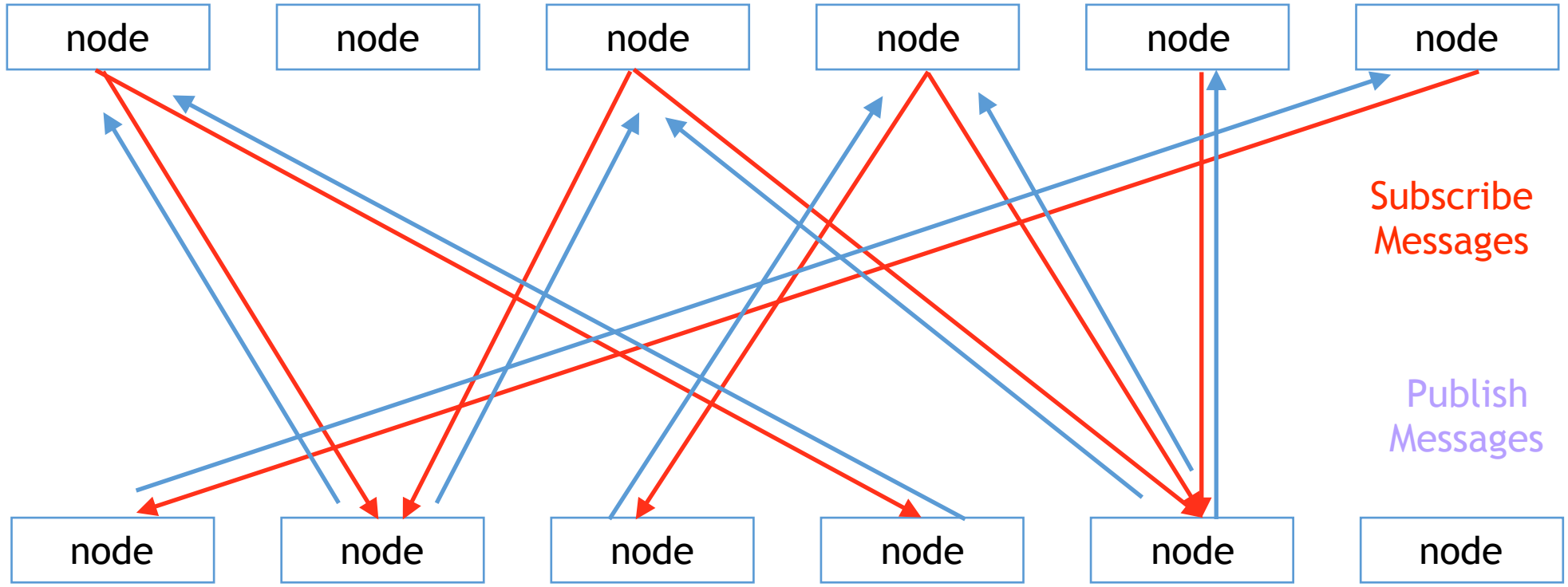
Software Defined Networks

Software Defined Networks

Messaging Schemes

- Polling
  - Slow, high latency
- Interrupts
  - Can have high latency due to save/restore
- “Push Status”
  - Critical control/status information conveyed point-to-point when it occurs
- Publish/Subscribe
  - For many recipients
  - Like “Push Status”, but recipients request to be informed (subscribe)
  - When an event occurs, status is published (pushed) to all subscribers

Messaging Schemes (con't)



See also: MQTT.org A lightweight publish/subscribe M2M protocol

Wireless Protocols

Leading Wireless Protocols

- Long Range Wireless Communication protocols, and Low-Power Wide-Area-Network (LPWAN), aka Low-Power Network (LPN), aka Small-Cell Networks (SCN)
  - Cellular
  - LoRa (LoRaWAN)
  - Ingenu
  - WiMAX
- Short Range Wireless Communication protocols
  - ANT+
  - Bluetooth Smart (BLE)
  - ZigBee
  - WiFi
  - NFC
  - EnOcean
  - Wireless HART
  - Z-Wave
  - 6LoWPAN

Long Range Wireless Protocols

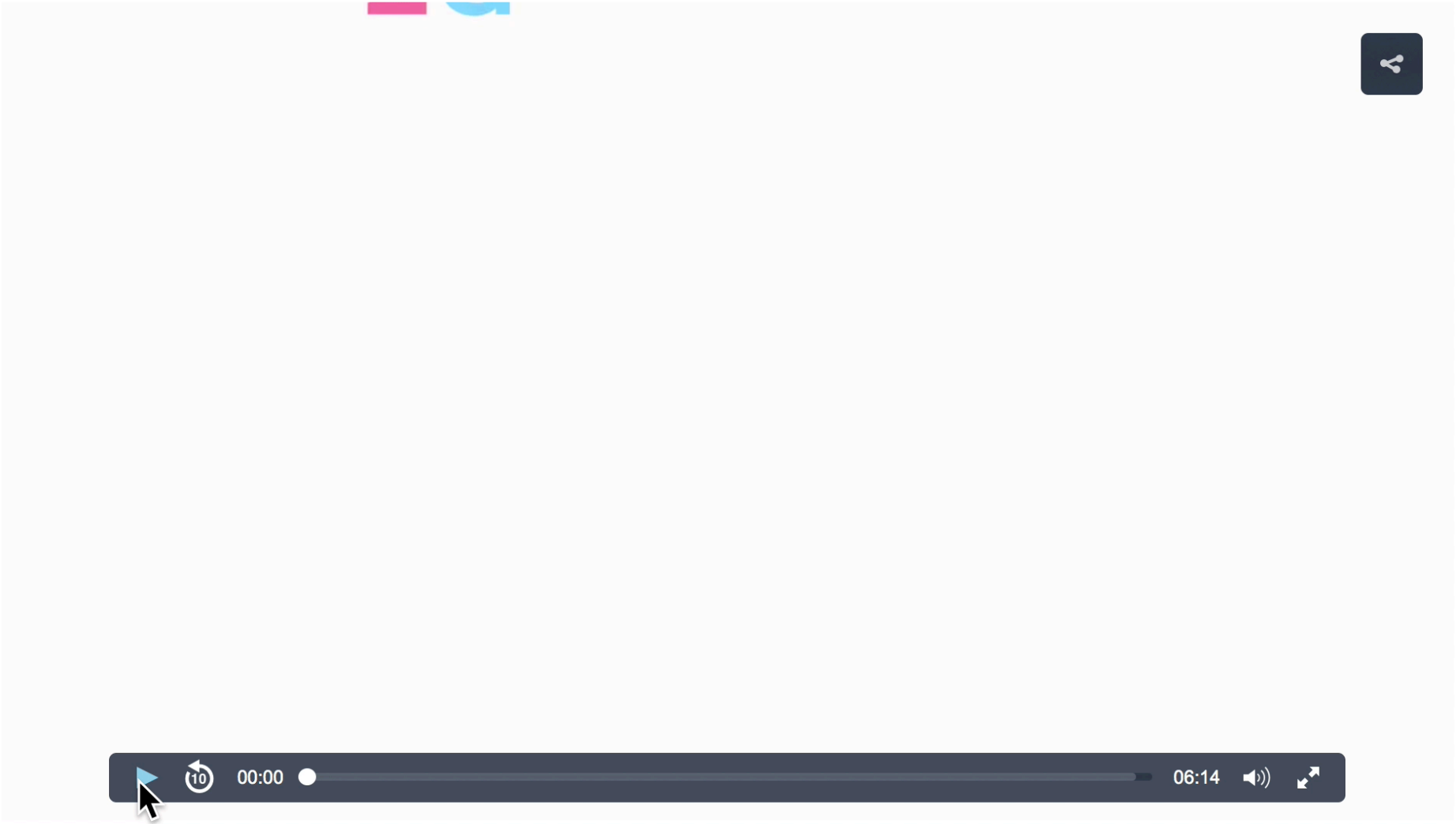
Cellular

- GSM, 4G/LTE
- You know the players in the US
- Range: 5 - 30 km
- Speed:
  - ATT LTE Denver, 28 Mbs down, 6.5 Mbs up
  - Verizon Denver, 4.9 Mbs down, 1.8 Mbs up (iPhone 5S)

Cellular - 5G

- http://spectrum.ieee.org/video/telecom/wireless/everything-you-need-to-know-about-5g?utm_source=Tech+Alert&utm_medium=Email&utm_campaign=TechAlert_02-02-17&bt_ee=9+hbB4prLYKxB1Ew5QEbE4wCKC4KRCOiTbOEUPzSv8uKDcqCucXdaeyuYwzfZTtz&bt_ts=1486061848685

Cellular - 5G



By Amy Nordrum, Kristen Clark and IEEE Spectrum Staff
Posted 27 Jan 2017 | 19:00 GMT

LoRa WAN

- https://www.lora-alliance.org/What-Is-LoRa/Technology
- Topographies: Star
- Range: Several (1-3) km
- Speed: 0.3 to 50 Kbs

LoRa WAN

Ingenu

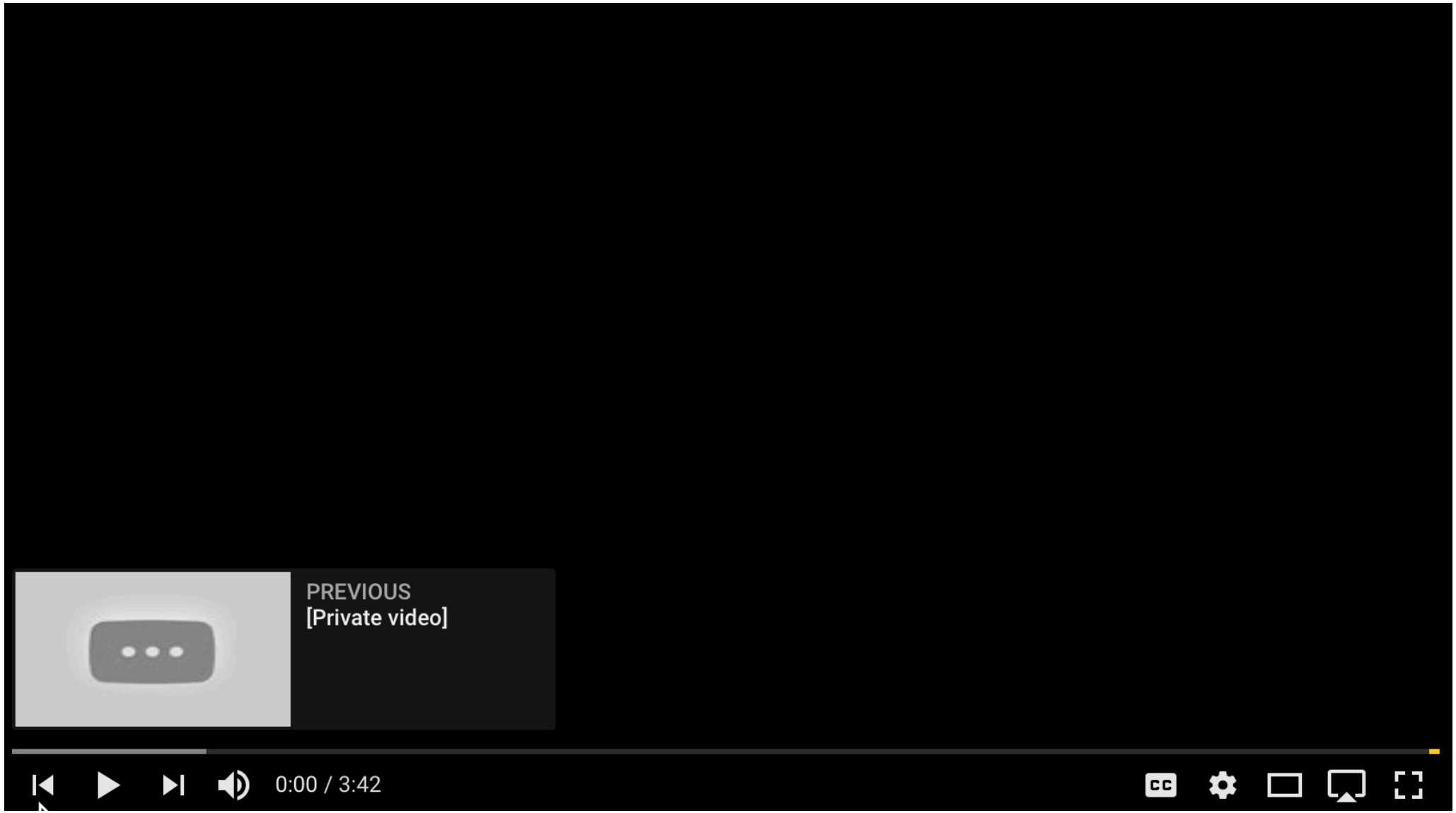
- http://www.ingenu.com
- Topographies: ? star
- Range: Up to 50km
  - 17 towers cover Dallas/Ft Worth area (2000 sq. miles)
- Speed: “low data needs”

Ingenu

WiMAX

- Worldwide Interoperability for Microwave Access
- Designed for the “last mile”
- Video/demo: https://www.youtube.com/watch?v=Tzna27LgBSk&list=PL6D14AD2104D5BE40&index=4
- https://standards.ieee.org/about/get/802/802.16.html
- Topographies: mesh
- 2-60 GHz, depends on the country
- Range: 10km
- Speed: ~ 70 Mbs (depending on antenna)

WiMAX



Short Range Wireless Protocols

Bluetooth Smart (BLE)

- https://www.bluetooth.com
- Ultra low-power
- Topographies: Peer-to-peer, mesh
- 2.4 GHz
- Range: < 10m
- Speed: 1-2 Mbs

ANT+

- https://www.thisisant.com/consumer/ant-101/what-is-ant/
- Ultra low-power
- Topographies: Star, peer-to-peer, mesh
- 2.4 GHz
- Range: < 10m
- Speed: 1-2 Mbs (competes with bluetooth)

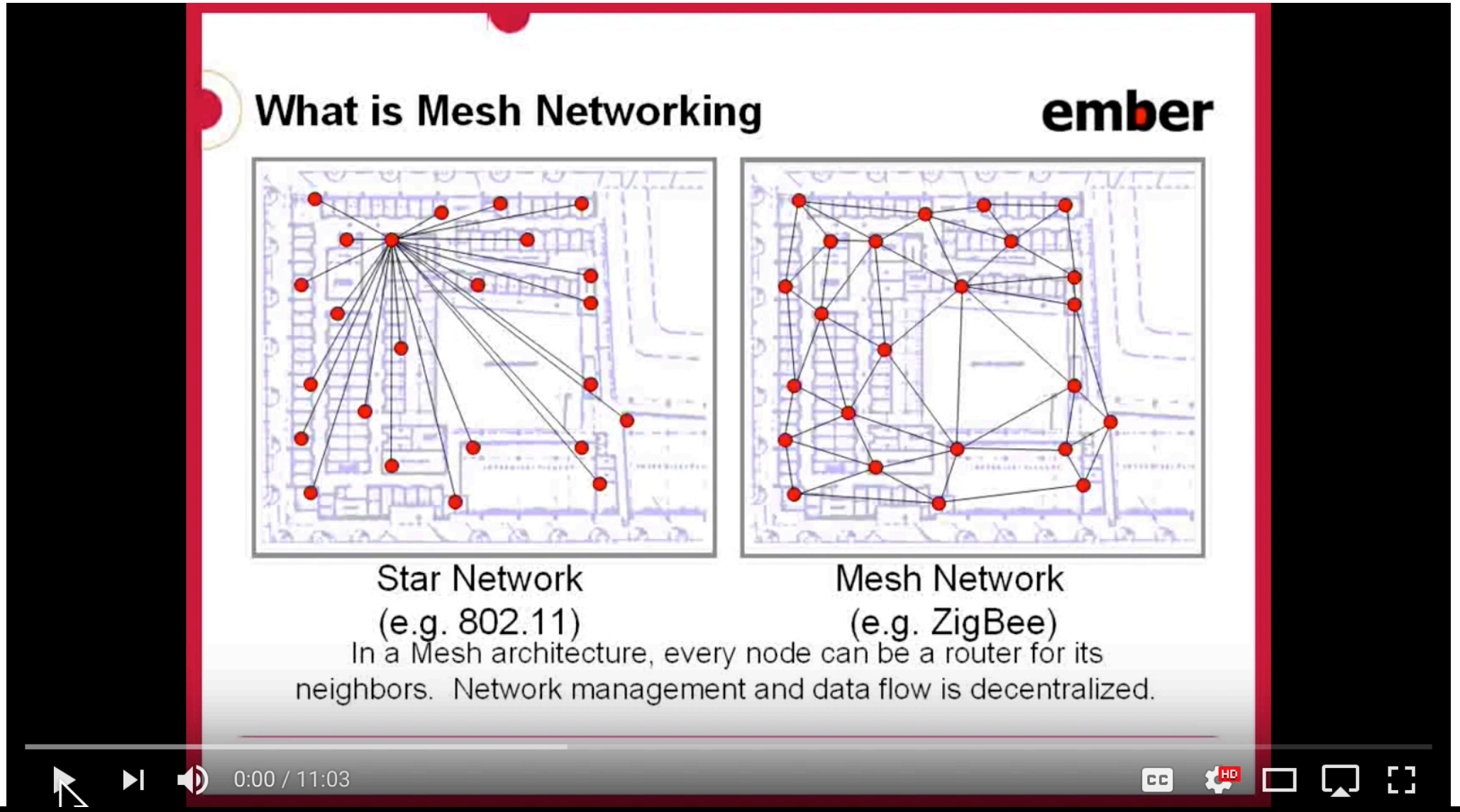
WiFi (802.11n)

- IEEE 802.11
- Topographies: Peer-to-peer
- 2.4 and 5 GHz
- Range: 20-80m
- Speed: 54 - 600 Mbs (54 is current)

ZigBee

- http://www.zigbee.org
- Ultra low-power
- Topographies: Mesh
- 2.4 GHz
- Range: ~20-80m
- Speed: 20 - 250 Kbs (competes with Wifi)

ZigBee Architecture



Wireless HART (WHART)

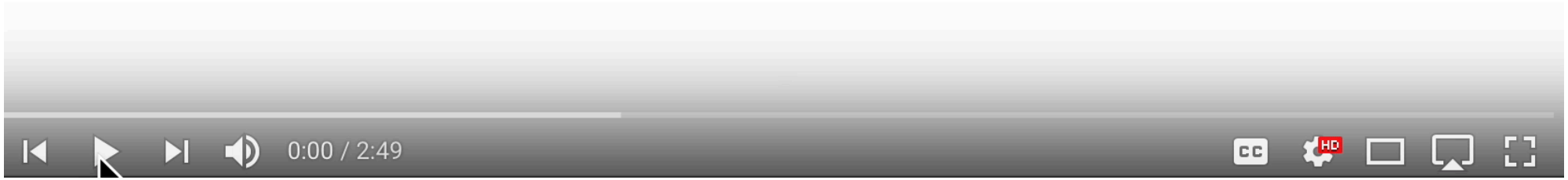
- https://fieldcommgroup.org/technologies/hart/hart-technology
- Topographies: Mesh
- 2.4 GHz
- Range: nominal ~ 200m
- Speed: 20 - 250 Kbs (competes with Wifi)
- Specific for industrial wireless sensing
- https://www.youtube.com/watch?v=WFASdYPzjvQ

Wireless HART (WHART)

EnOcean

- https://www.enocean.com/en/
- Ultra low power, energy harvesting, self-powered
- Topographies: Peer-to-peer
- 800-900 MHz, 2.4 GHz
- Range: ~ 30m indoor range
- Speed: 2 Mbs (competes with Wifi, but lower speeds)
- Also supports ZigBee and Bluetooth Smart
- https://www.youtube.com/watch?v=n0DEQlOZm8Y&list=PLXmn2hE1zXxpEnL0x0K6WH9nYpMwRuVnf

EnOcean



Z-Wave

- http://www.z-wave.com
- Home automation focus: lights, locks, thermostats
- Topographies: Peer-to-peer
- 908.42 MHz
- Range: 100m (competes with Wifi)
- Speed: ~ 40 Kbs (but lower rates than Wifi)

6LoWPAN

- IPv6 Low-rate Wireless Personal Area Network
- http://https://standards.ieee.org/about/get/802/802.15.html
- Topographies: mesh
- Basis of ZigBee and Wireless HART
- Started out as a 2.4 GHz spec, expanding: sub-1 GHz, Bluetooth Smart, Power-Line-Control (PLC), low-power WiFi

Source: http://www.ti.com/lsds/ti/wireless-connectivity/6lowpan/overview.page

NFC

- ISO/IEC 18000-3
- Ultra low (or no) power
- Topographies: Peer-to-peer
- 13.56 MHz
- Range: ~ 10cm
- Speed: 106 - 424 Kbs

End