UPISC UNIVERSITY OF PITTSBURGH INFRASTRUCTURE SENSING COLLABORATION WORKSHOP

NATIONAL ENERGY TECHNOLOGY LABORATORY

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Chris leads sensor, data acquisition, wireless network, and embedded microcontroller development efforts at GTI. He has worked with the LoRa Alliance and the Wi-SUN Alliance to promote an open standard ecosystem for interoperability in the wireless sensor space. Chris currently directs the Instrumentation, Controls, and Connected Systems (ICCS) department of GTI Energy.

Open-Standards Communication Networks for Sensor Data

UPitt Infrastructure Sensing Collaboration Workshop – November 8, 2023

Chris Ziolkowski
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GTI ENERGY
solutions that transform

GTI Energy Background

- GTI Energy is a leading research and training organization focused on developing, scaling, and deploying innovations that support low-carbon, low-cost energy systems.
- Our energy solutions transform lives, economies, and the environment.
- We embrace systems thinking, open learning, and collaboration to solve for some of the world's greatest energy challenges.
- With 28 laboratory facilities and five offices across the U.S., GTI Energy leverages the expertise of our trusted team of scientists, engineers, and partners to deliver impactful innovations needed for low-carbon, low-cost energy systems worldwide.

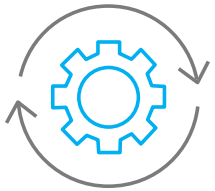
Working across the energy value chain

Source

Expanding supplies of affordable, clean energy

- Subsurface production of hydrogen
- Enhanced geothermal systems
- Unconventional natural gas and oil production
- Geologic modeling and reservoir characterization
- Hydraulic fracturing diagnostics and optimization
- Hydraulic fracturing and reservoir flow modelling
- Enhanced recovery

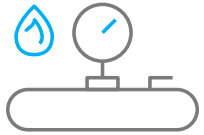
Make



Transforming natural resources into clean energy

- Hydrogen production
- Integrated biofuels technology R&D
- Syngas generation and processing
- Carbon management
- CO_2 capture and utilization
- Chemical research and process development
- Renewable natural gas and gas quality
- Gasification process development

Move & Store



Ensuring safe and reliable energy infrastructure

- Methane emissions, monitoring, mitigation, and reduction
- Data integrity and risk management
- Infrastructure rehabilitation and improvements
- Environmental matters, enabling renewable gas, and gas quality
- Smart utility information technology tools
- Materials and analytical testing
- CO_2, H_2, and natural gas underground storage

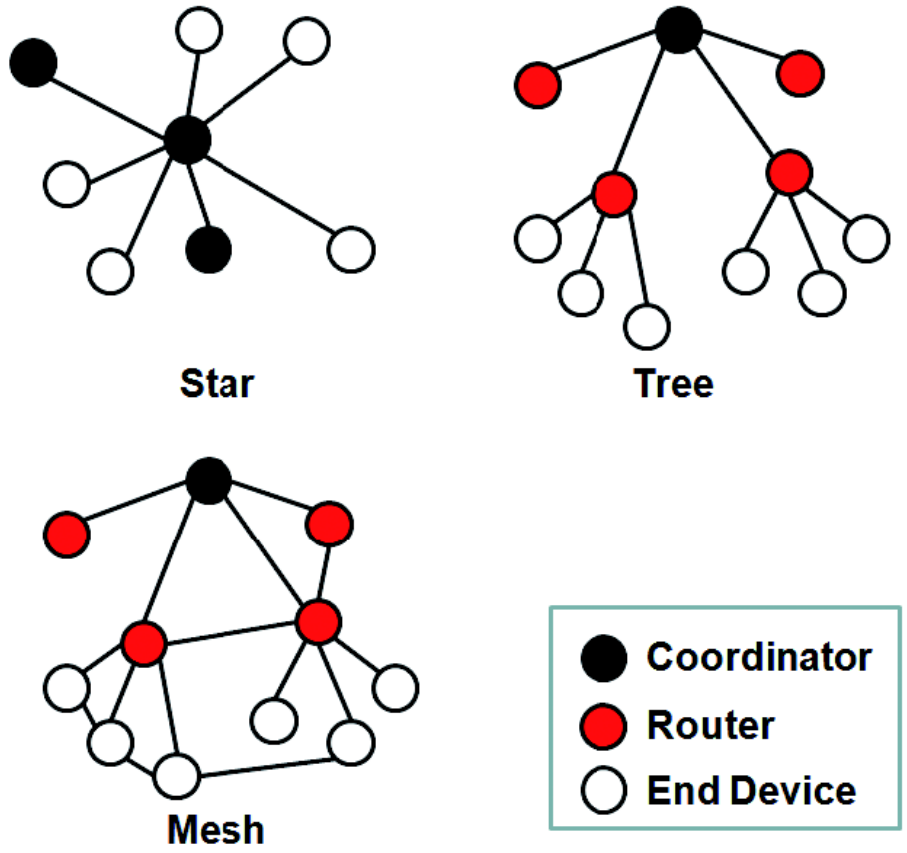
Use

Delivering solutions for efficient and environmentally responsible energy use

- Residential/commercial appliances, equipment, and building systems
- Industrial process heat and steam
- Power generation and combined heat and power
- Alternative transportation fuels
- Natural gas-solar thermal hybrid equipment
- CO_2 capture and utilization

The objectives of this presentation:

- Provide an overview of two open-standard wireless communication ecosystems.
  - Wi-SUN Alliance
  - LoRa Alliance
- Discuss the differences between mesh and star networks.
- Discuss use cases for various network implementations.



Utilities need to maintain **two** major artifacts:

- The physical utility infrastructure.
- The data describing that infrastructure.
  - Decisions made about first are based on the second.
  - Good decisions require data that is complete, current, and accurate.
  - Sensor data can keep the physical and digital worlds in sync.

What is needed to make use of sensor data?

- An application for data visualization and manipulation at the operator network edge.
- Analytical tools to work with the data.
- Data storage accessible to the operator application and to the sensors.
- **Open standards for communication and interchange of data.**
- External (to the utility) data sources such as weather, fires, seismic, or markets.
- Sensors and actuators at the physical infrastructure network edge.

LoRaWAN Alliance Mission

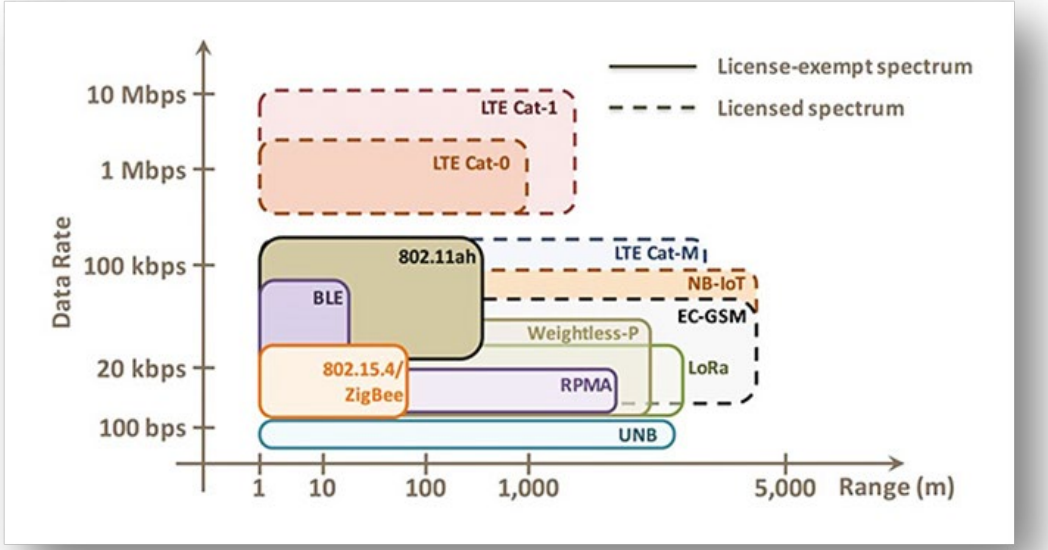
- Efficient TCO (total cost of ownership)
  - LoRaWAN operates in the Industrial, Scientific, Medical band in North America (ISM 915 MHz) which is unlicensed spectrum **regulated by the FCC**; the ISM band supports over 80 million (and counting) commercially deployed smart utility meters in the U.S. today
  - A single LoRaWAN gateway is not only long range but also **high capacity** and able to support tens of thousands of LoRaWAN end-devices and millions of transmissions per day from and to those end-devices
  - LoRaWAN is architected for long end-device battery life *(for example, a utility connected natural gas meter can run autonomously for **20 years** with no battery maintenance)*

Wi-SUN Alliance Mission

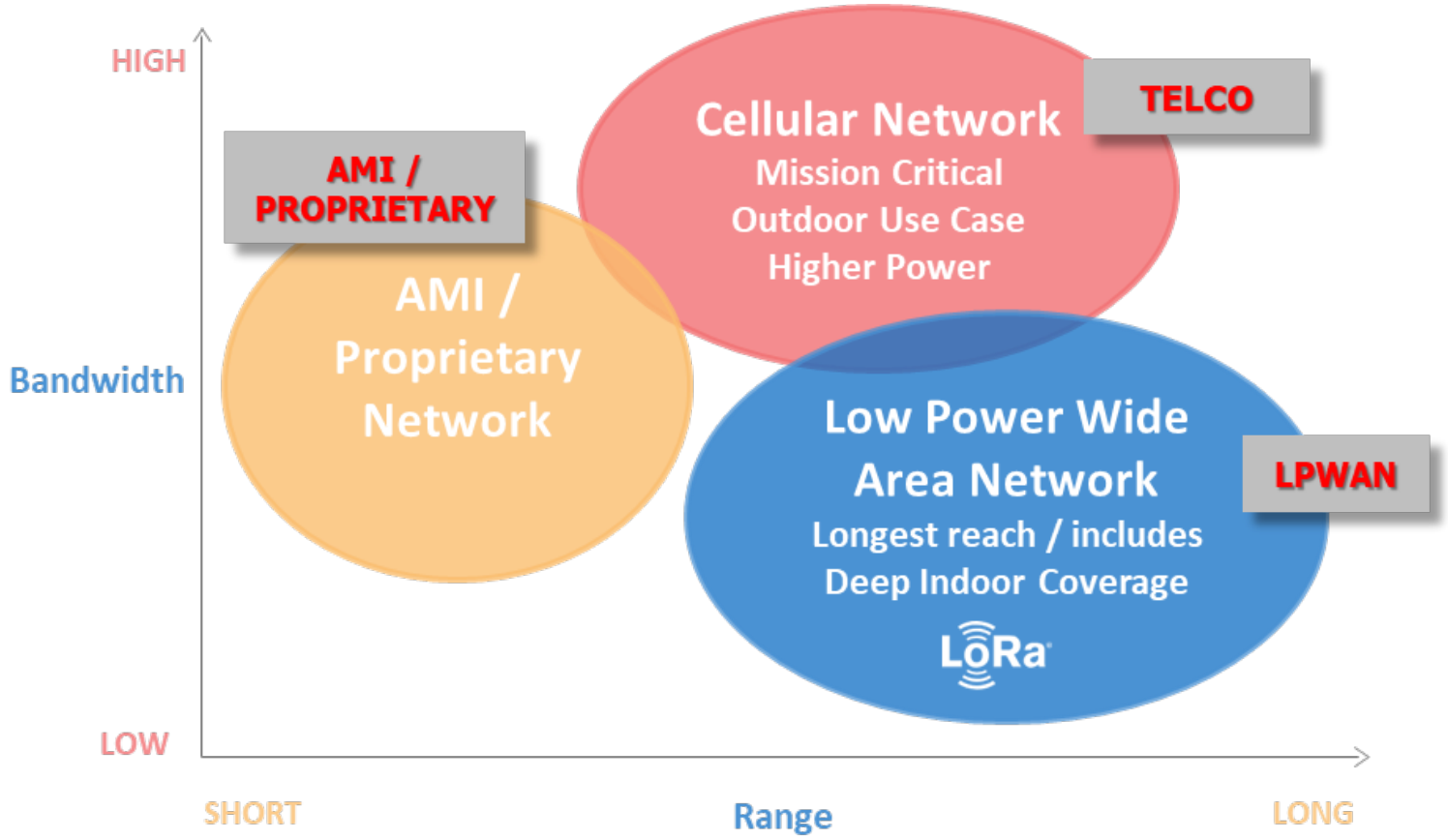
- Promotes multi-vendor interoperability, vendor competition, and customer choice
- Global reach and applicability
- Enables diverse ecosystem of solution providers including product vendors, silicon vendors, cities, utilities, government institutions, and academia to collaborate on smart solutions
- Robust certification program to ensure interoperability, for wireless devices for outdoor Field Area Networks (FAN), Home Area Networks (HAN) and other IoT networks

Wireless Network Choices - General

- Low-Power Wide Area Networks (LPWAN)
  - Built for machine-to-machine(M2M) communications.
  - Small packets, infrequent transmissions, low power, harsh wireless environments.
  - LoRaWAN, Matter, RPMA, ~~Sigfox~~
  - LTE-CATM1, NB-IoT
- What are the range, power, and latency requirements for your use-case?



Wireless Network Choices - Utility



Low Power Wide Area Network
Addresses Deep Indoor Connectivity

Cellular Network
Good fit for outdoor coverage

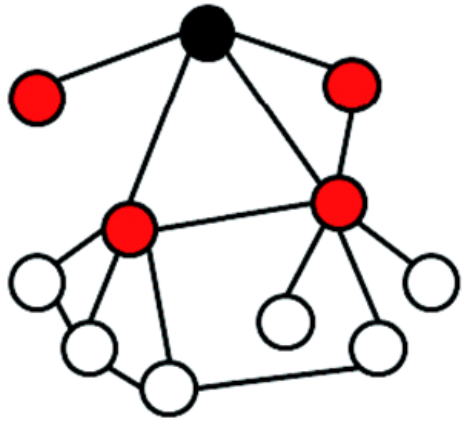
AMI / Proprietary
Requires meshing to extend range
Good fit for AC powered devices

Open versus Proprietary Considerations

- Open Standard Networks
  - Diverse ecosystem with products from multiple vendors.
  - Diversity can complicate provisioning and commissioning.
  - User can build out or lease wireless coverage.
- Proprietary AMI Networks
  - Commodity devices optimized for metering; other sensing functions are possible.
  - Vendor lock-in for hardware and support services.
  - User must build out wireless coverage.
- Telco Based Networks.
  - Coverage is ubiquitous but can be sunset.
  - Built out and maintained by vendor, included in fee structure.

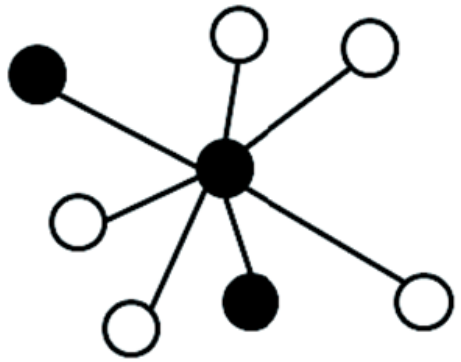
Examples of Wireless Mesh Networks

- Open Standard Mesh Networks
  - Wi-SUN Alliance (https://wi-sun.org/)
  - ZigBee (https://csa-iot.org/)
- Proprietary Advanced Metering Infrastructure (AMI)
  - Itron Silver Springs AMI
  - Landis Gyr AMI
- These mesh networks use the IEEE 802.15.4 physical layer (PHY) standard
- Upper layers of the protocol stack can be open or proprietary
- Future Itron and Landis Gyr products could be Wi-SUN interoperable.



Examples of Wireless Star Networks

- Open Standard Star Networks
  - LoRa Alliance (https://lora-alliance.org/)
  - Wireless M-Bus (https://m-bus.com/)
- Proprietary Advanced Metering Infrastructure (AMI)
  - Itron “Classic” AMI
  - Sensus AMI
- Telco Based Star Networks.
  - LTE-CATM1
  - NB-IoT

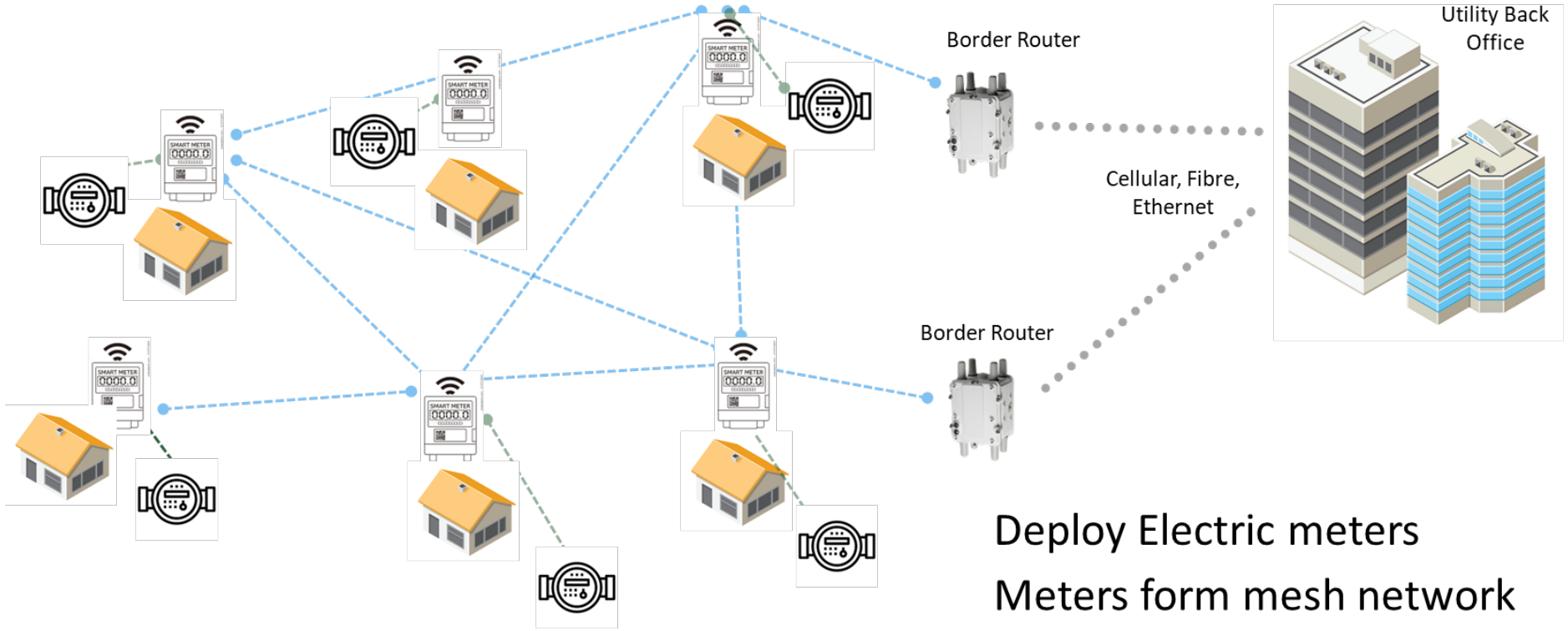


Star

Mesh versus Star Considerations

- Not all nodes in a mesh network can be low power because of message “hopping”.
  - Some mesh nodes must be active 24/7 to receive, store, and forward messages.
  - Battery powered, “sleepy”, nodes must be in range (200m) of an active node.
  - A node can be several hops from the mesh edge, adding latency.
  - The hop route can vary if the active nodes have issues.
- Any node in a star network can be low-power with long battery life.
  - The gateways at the mesh edge must have 24/7 power.
  - A gateway can serve several thousand sensor nodes.
  - There must be at least one gateway within range (5000m).
  - Sensor node messages are received redundantly by any gateway in range.

Multi-Utility Mesh Network Evolution



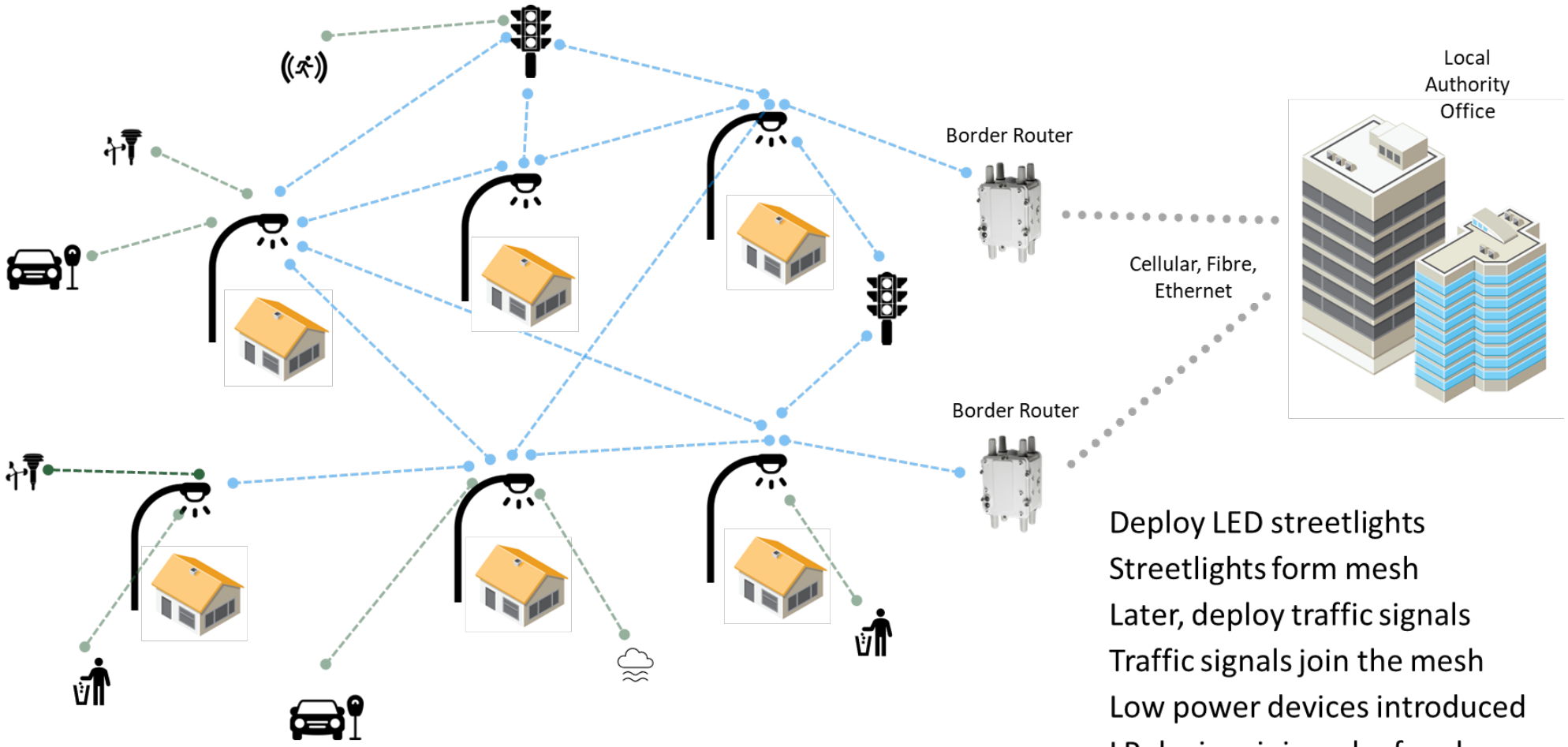
Deploy Electric meters

Meters form mesh network

Deploy Water meters

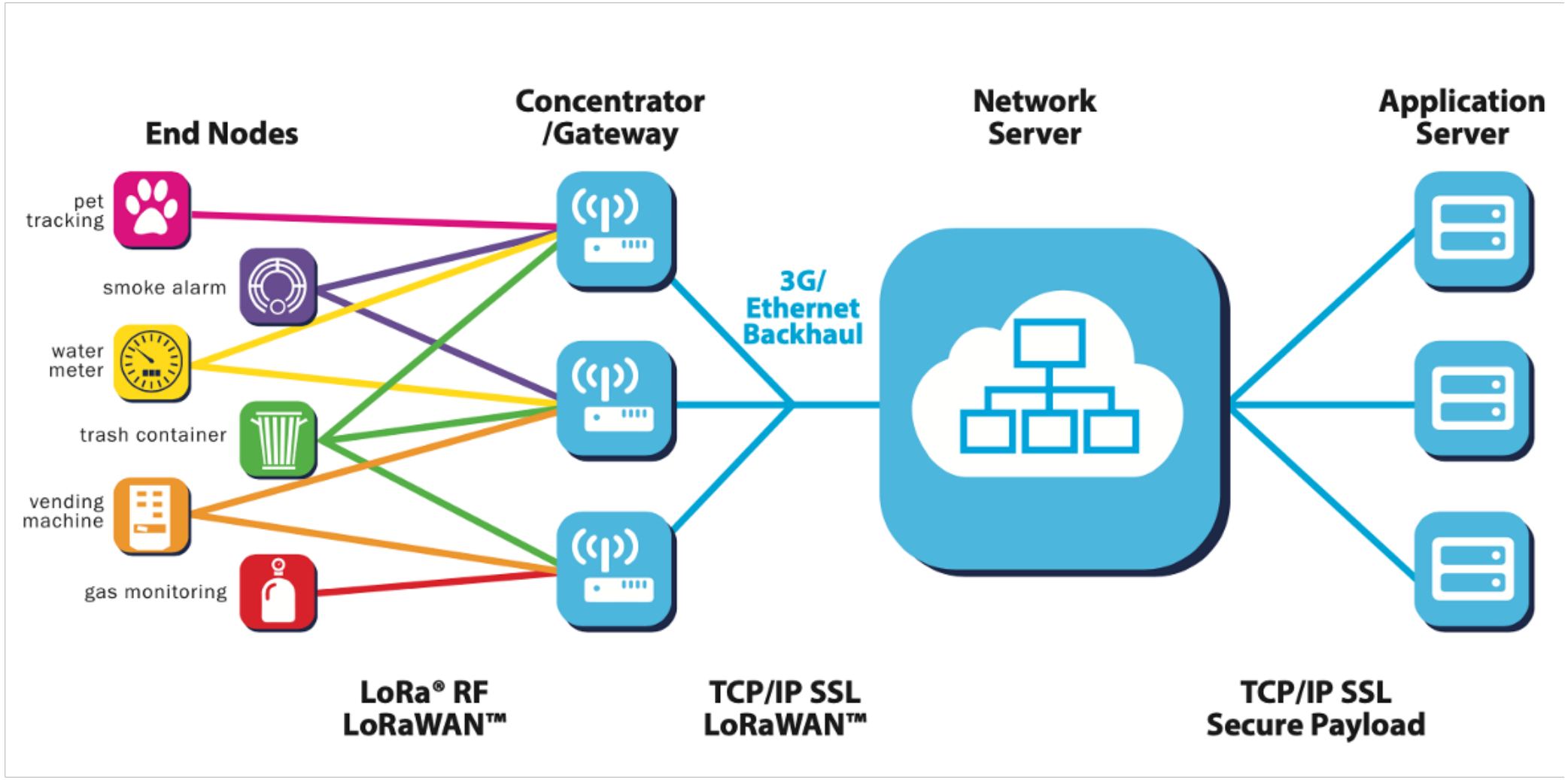
Water meters join as low power nodes

Smart City Mesh Network Evolution



Deploy LED streetlights
Streetlights form mesh
Later, deploy traffic signals
Traffic signals join the mesh
Low power devices introduced
LP devices join as leaf nodes

Star Network Evolution



Criteria for Network Selection

- **Value:** Is the data mission critical? Critical enough to consider redundant coverage?
- **Velocity:** How often does the data change? What degree of latency is allowable?
- **Volume:** Is the amount of data generated by a single sensor node large or small?
- **Vicinity:** Are there many sensor nodes in a geographic area? Are you dealing with a remote, isolated sensor node?

Conclusions

- Open standards are the best means to “future-proof” your wireless sensor network. They avoid the issues of vendor lock-in for hardware or network services.
- Starting with a clean sheet of paper, the choice of star or mesh should be driven by the value/velocity/volume/vicinity criteria.
- Long range star networks can be rolled out quickly for a low number of sensor nodes and scaled up as needed.
- Mesh networks are effective in a vicinity with a high number of sensor nodes and the ability to support some 24/7 nodes (combo electric and gas/water).
- Some proprietary mesh networks now in place may be Wi-SUN interoperable in the future. At least one legacy vendor has committed to future products that can run either the proprietary stack or the Wi-SUN stack.

Thank You
Questions?

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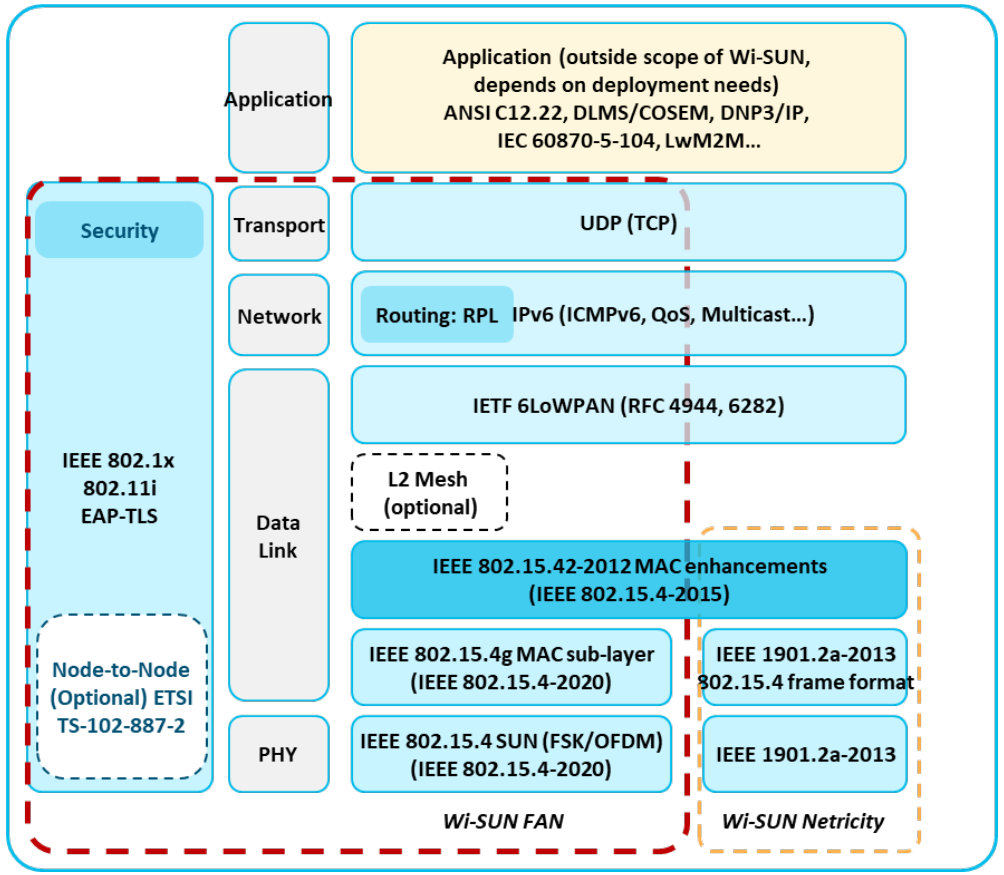
Extras – Wi-SUN FAN Stack



IPv6 protocol suite

- UDP
- 6LoWPAN Adaptation + Header Compression
- DHCPv6 for IP address management
- Routing using RPL
- ICMPv6
- Unicast and Multicast forwarding

Security

- 802.1X/EAP-TLS/PKI Authentication
- 802.11i Key Management
- Optional ETSI-TS-102-887-2 Node 2 Node Key Management

MAC based on IEEE 802.15.4e + IE extensions

- Frequency hopping
- Discovery / Join
- Protocol Dispatch (IEEE 802.15.9)
- Several Frame Exchange patterns
- Optional Mesh Under routing

PHY based on 802.15.4g

- OFDM and FSK modulations, data rates, and regions

Extras – LoRaWAN Details