

# Connecting Interactive Devices

Rob Faludi  
October 2019

*A Practical Guide to the Zigbee Mesh Networking Protocol*

*Building*

# Wireless Sensor Networks



O'REILLY®

*Robert Faludi*



## Adidas Megalizer

Didier Brun  
Sneakers control the music

# Adidas Megalizer

---



# Why Connect?



# Value of Connecting

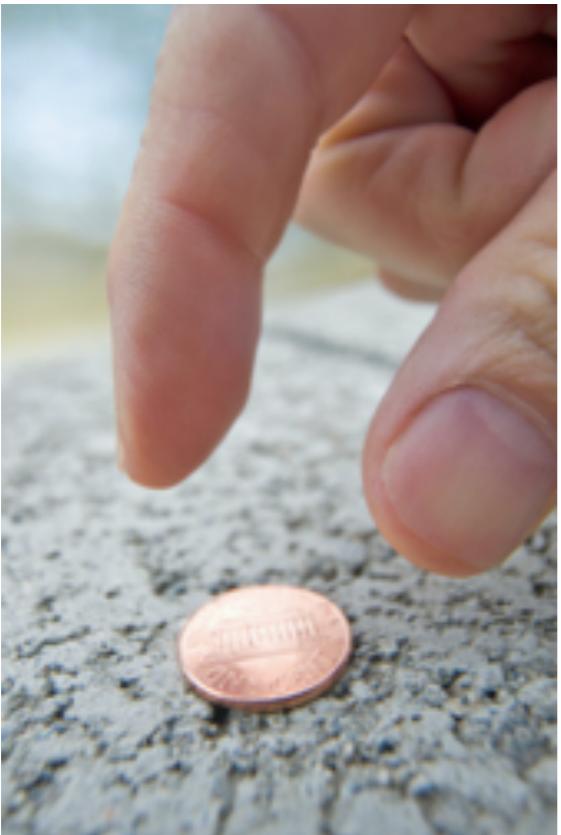
---

- groups of devices become greater than their parts
- data can be moved to better locations
- devices can coordinate with each other
- control can be maintained remotely

# Businesses connect to compete

---

- Improve existing revenue streams



- Create new revenue



- Improve customer satisfaction

# Many Benefits

---

- directly measure what customers use and when
- dynamic improvements to device operations
- instantly test new ideas in the field
- immediate insights from changes
- just-in-time supply chain
- service request prediction
- increased supplies revenue
- reduced support costs
- demand forecasts
- become a more responsive business
- remaining inventory
- regulatory compliance
- service opportunities
- service route optimization
- predictive maintenance
- on-time replenishment
- upselling opportunities
- trouble reports
- asset locations
- customer behaviors
- purchase predictors
- products can become services

# Consumers seek *perceived* benefits

---

- entertainment
- convenience
- health
- personal safety



# Artists want to create experiences

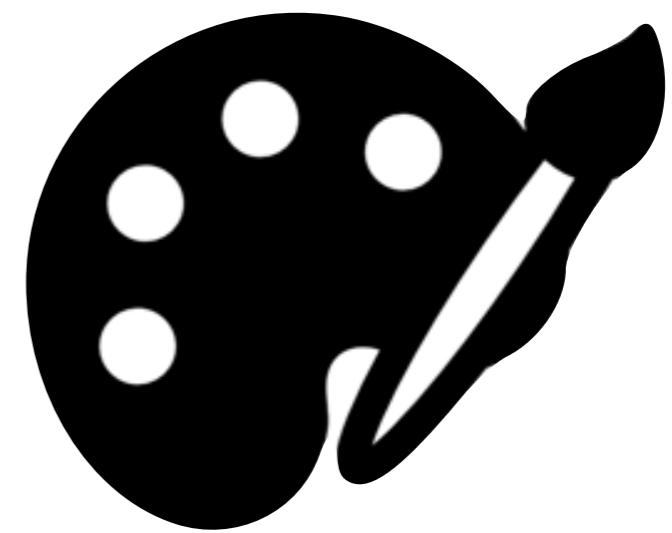
---

- entertain
- mystify
- impress
- frighten
- dazzle
- educate
- humanize
- ...and monitor installations in their absence





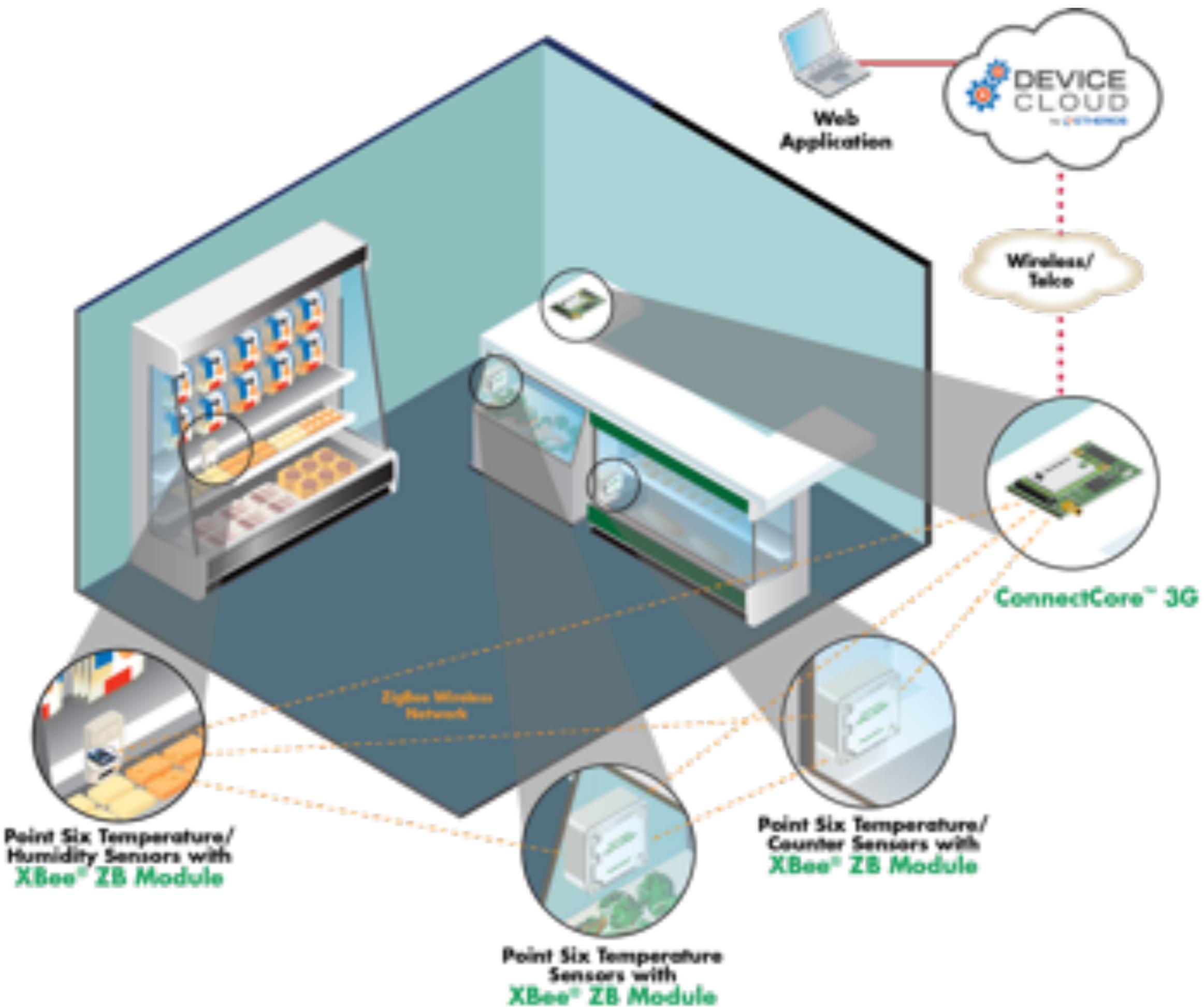
Examples

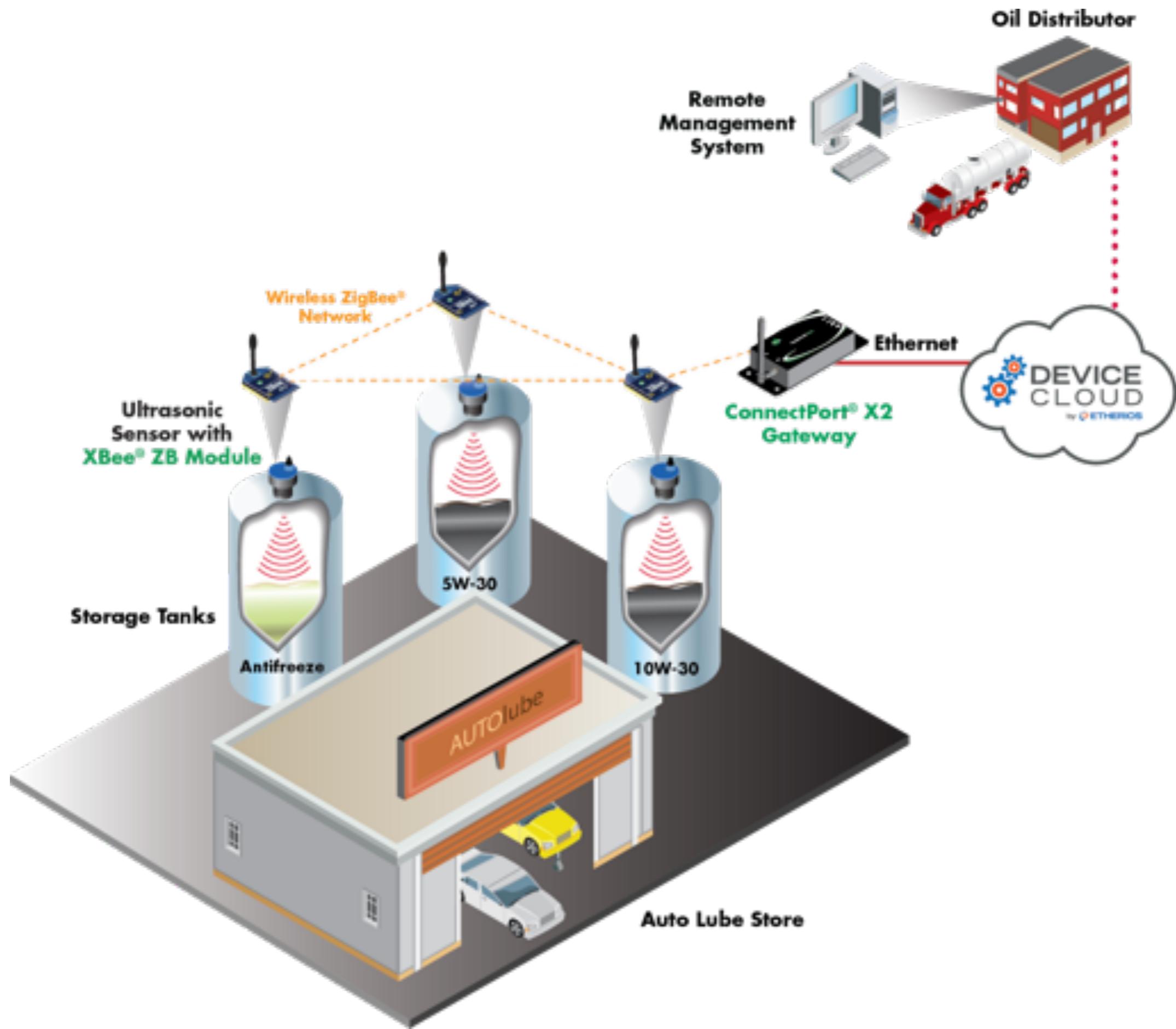


# Industrial Examples

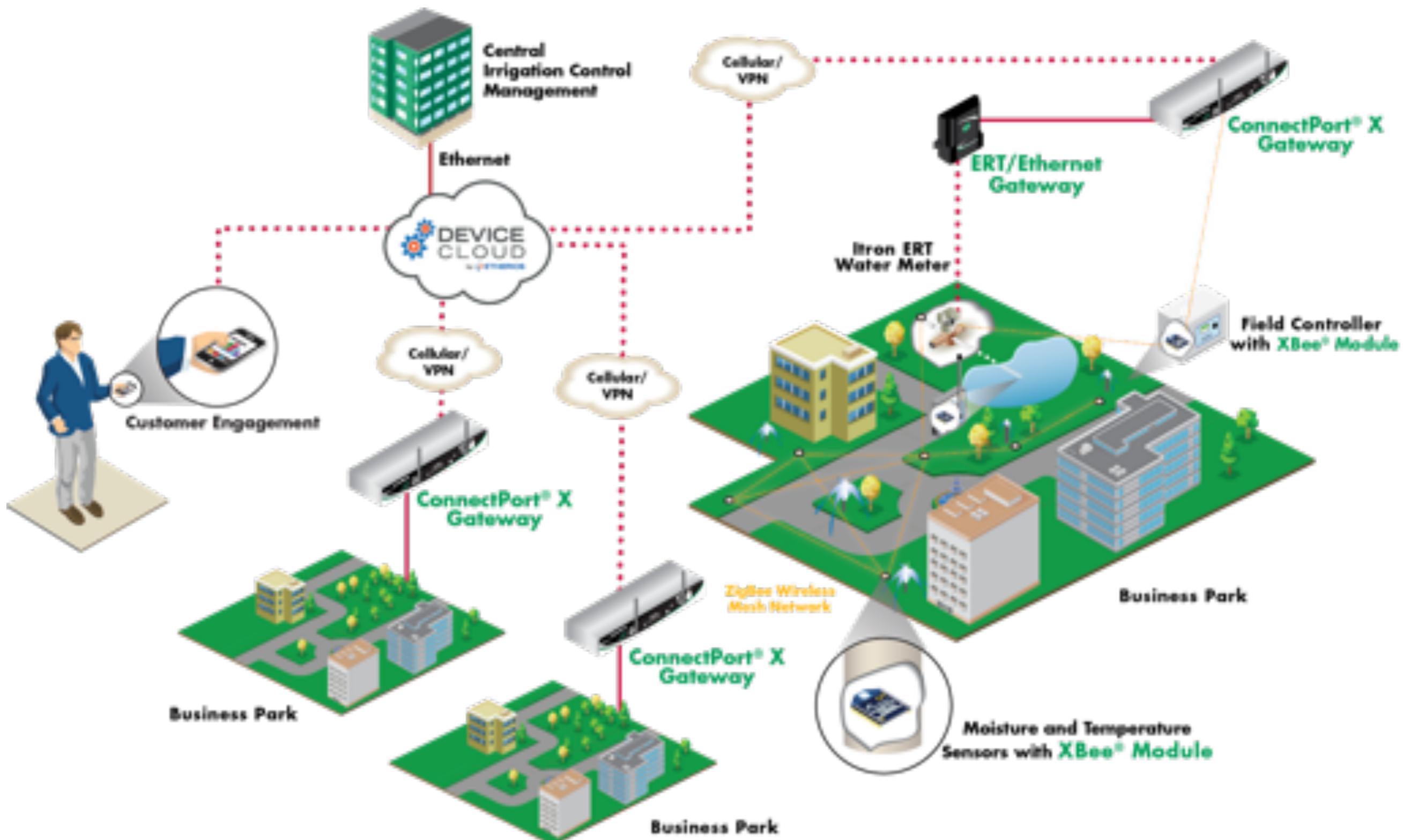
---

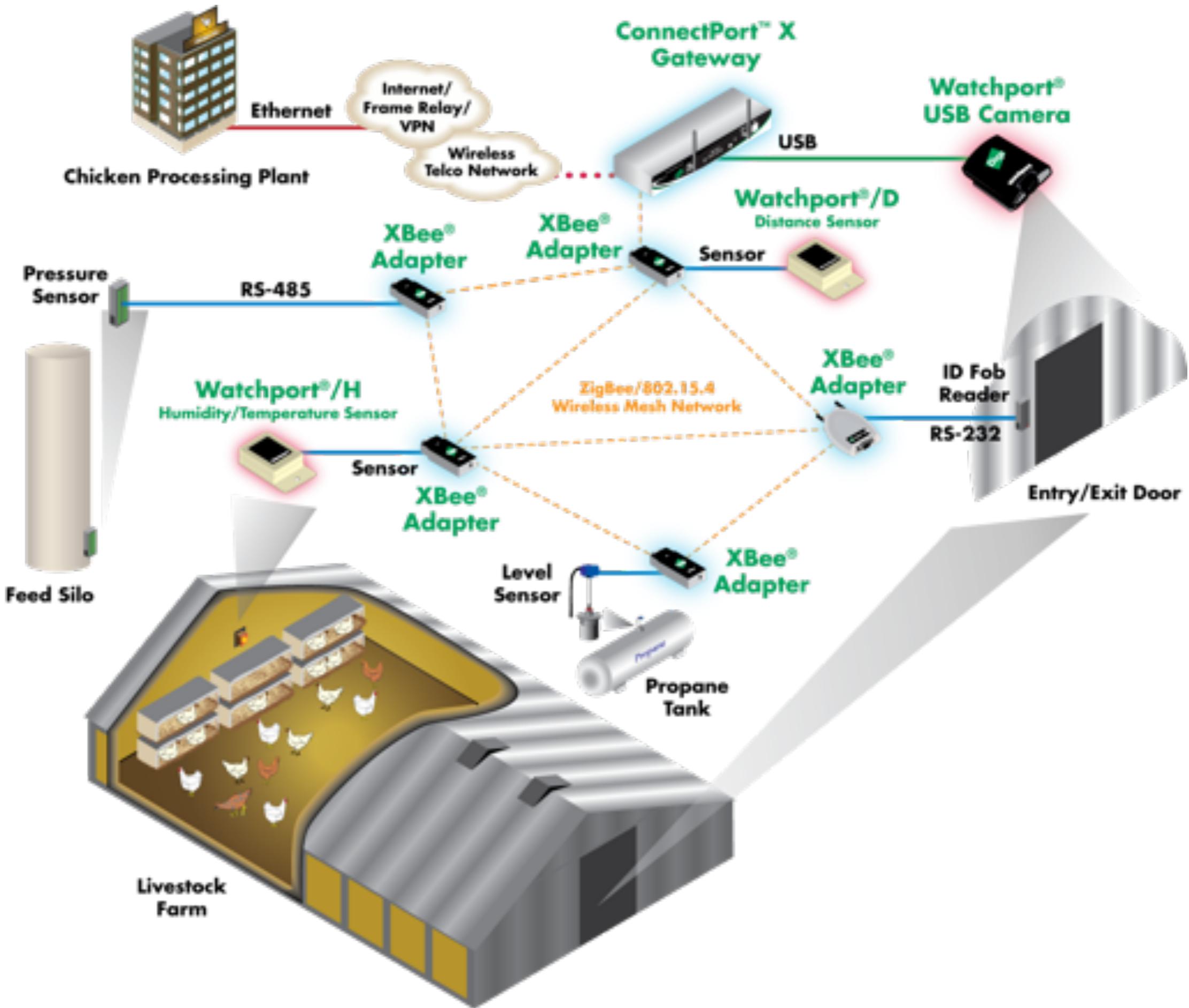


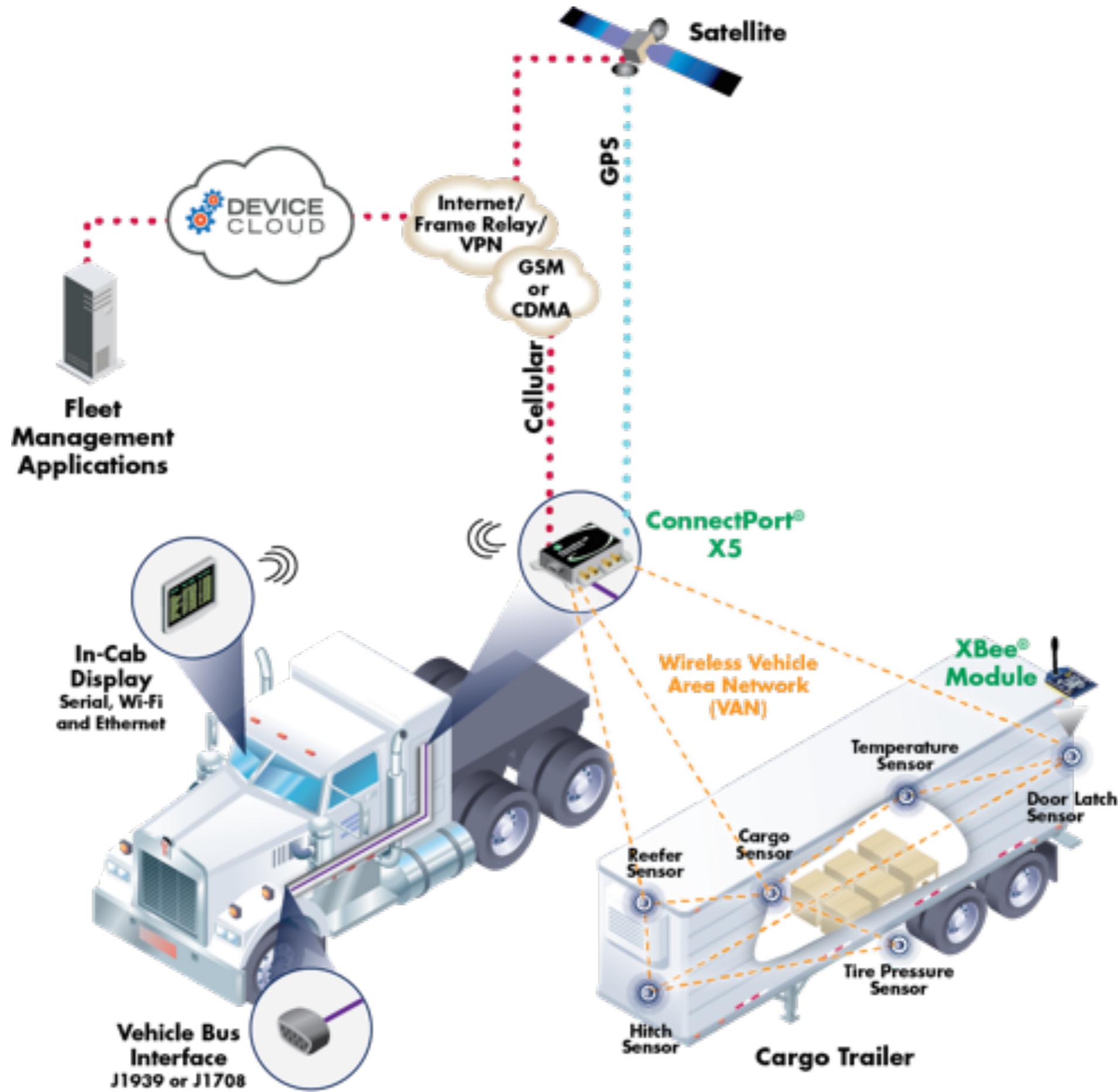












# Consumer Examples

---



# Consumer Examples

---



# Self-driving Trash Can

---



## Creative Examples





## Touched by Strangers

Alex Reeder & Yutaka Kitamura  
interactive dance performance suits



## Ciroc Moment

Daniel Hirschmann, Tom Sloan and Wanju Kim  
Networked social drinking interface



# The Pool

Jen Lewin  
collaborative interactive sculpture

# The Pool

---



JEN LEWIN  
The Pool



## Blendophone

John Park & Usman Muzaffar  
“musical” instrument made from eight blenders



## Dream Jammies

Alex Reeder, at ITP  
body aware pajamas for communicating across multiple time zones



# Roller Derby Hit Tracker

Tom Igoe

tracks body checks in roller derby; build one yourself



# KickBee

Corey Menscher  
Sends a tweet when your baby kicks





## Botanicalls

Rob Faludi, Kate Hartman, Kati London, Rebecca Bray  
plants phone you to discuss their needs



# Wayward Soles

Daniel Liss

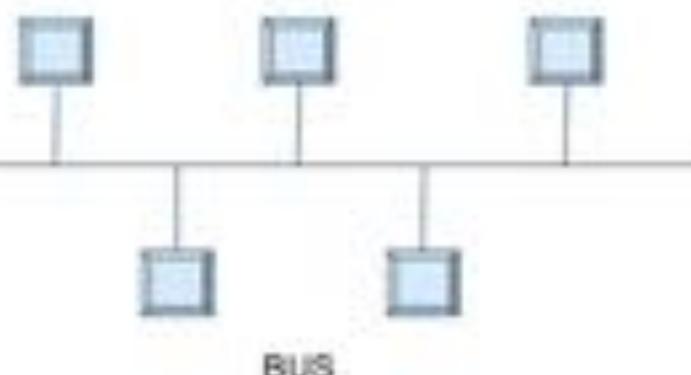
essentially, a when-is-daddy-getting-home device

# Making Connections

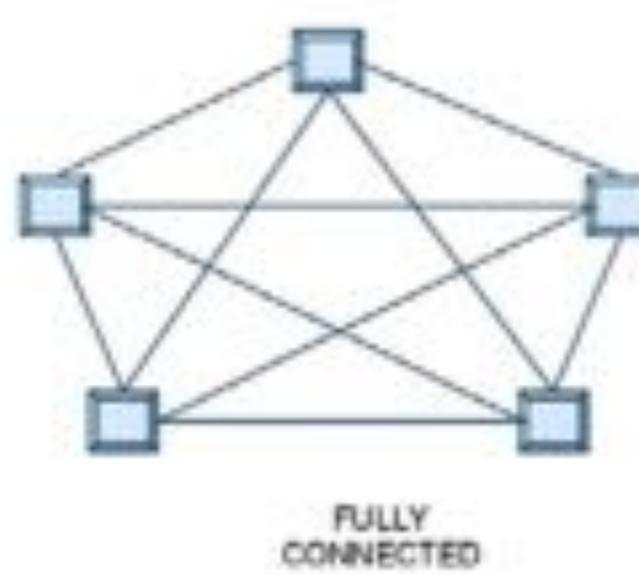


# What's a Network?

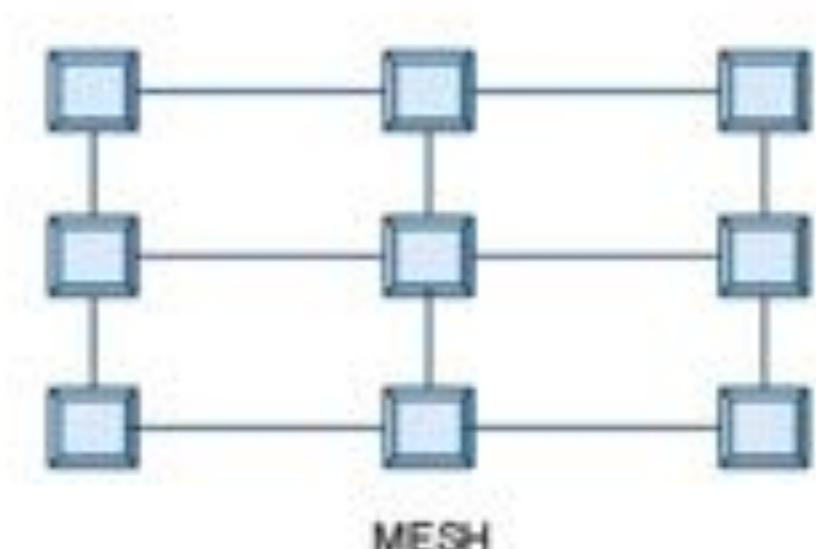
---



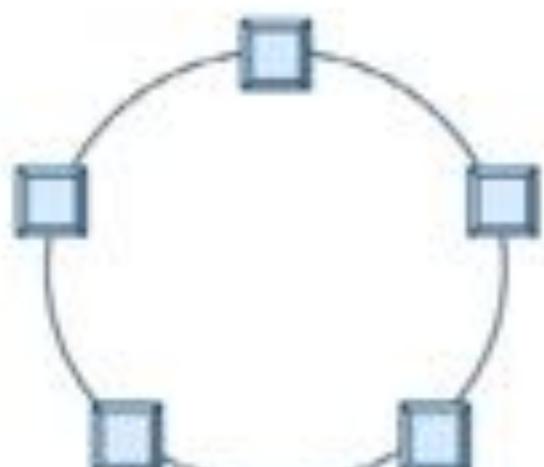
BUS



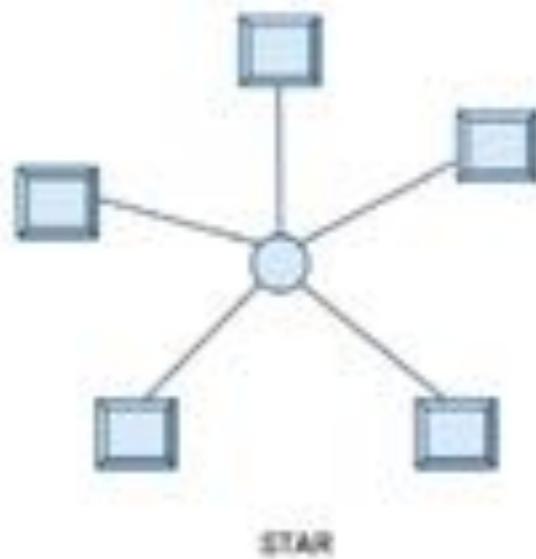
FULLY CONNECTED



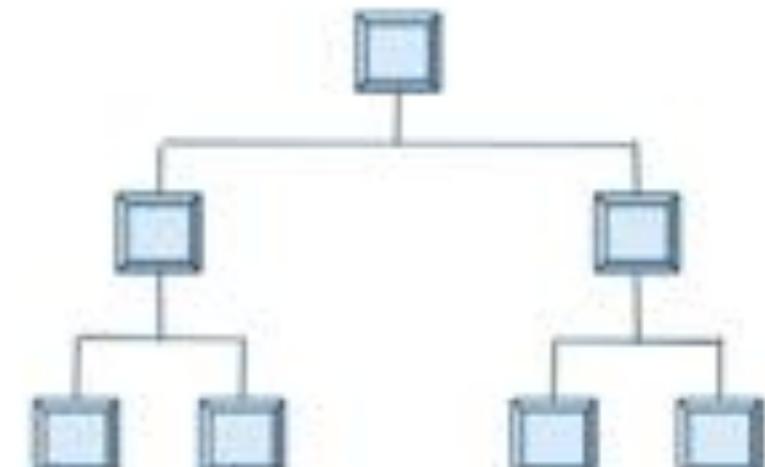
MESH



RING



STAR



TREE

# What's a Protocol?

---



A few  
communications  
protocols



# Serial

---

- basic and most common communications protocol
- RS-232, modems, USB
- board level:
  - TTL, SPI, I2C and more
- fast and reliable
- wired (generally)

# Ethernet

---

- very fast & stable
- easy provisioning
- reliable
- inexpensive
- tethered
- shrinking availability



# Wi-Fi

---

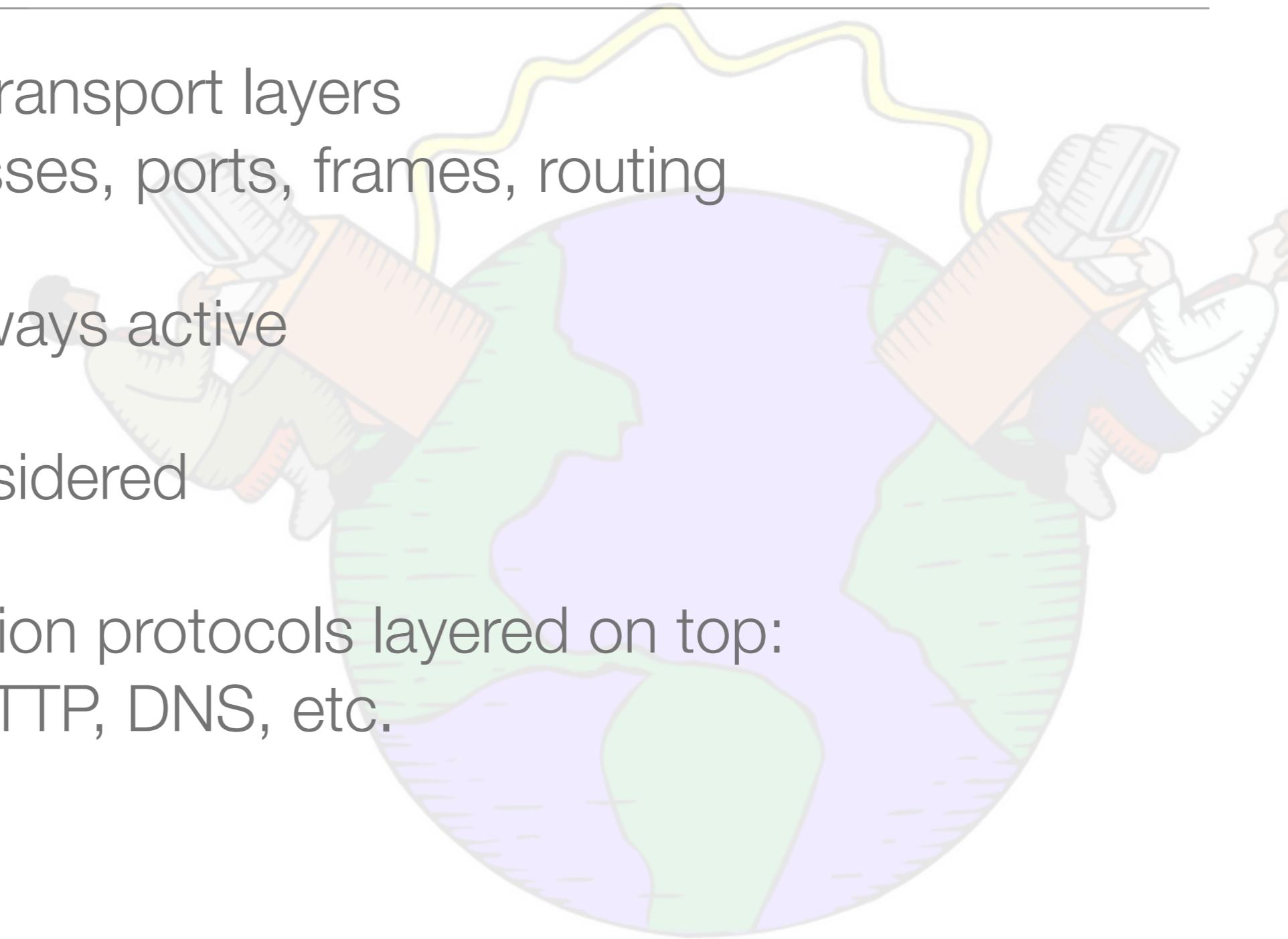
- very common
- 100-meter range
- provisioning can be difficult
- great on-ramp to Internet
- power hungry
- 2.4 GHz or 5 GHz for worldwide use



# The Internet TCP/IP (& UDP)

---

- network and transport layers  
define addresses, ports, frames, routing
- always on, always active
- sleep not considered
- Many application protocols layered on top:  
FTP, SMTP, HTTP, DNS, etc.



# MQTT - Message Queuing Telemetry Transport

---

- application layer, frequently on top of TCP/IP
- publish/subscribe
- lightweight
- small size
- low power usage
- minimized data packets



# RESTful HTTP - Representational State Transfer

---

- uses HTTP verbs GET, POST, PUT, DELETE, etc
- simple
- flexible
- stateless
- URL syntax
- efficiency concerns

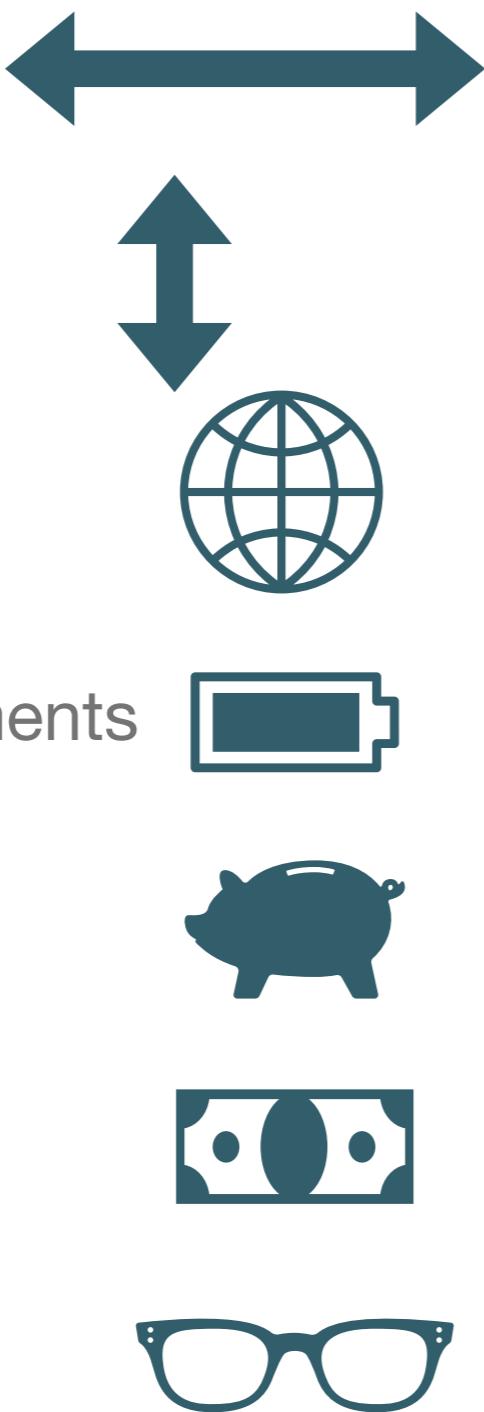




More Wireless

# Wireless Considerations

- range
- bandwidth
- coverage
- power requirements
- hardware cost
- service cost
- overall context



# NFC / RFID

---

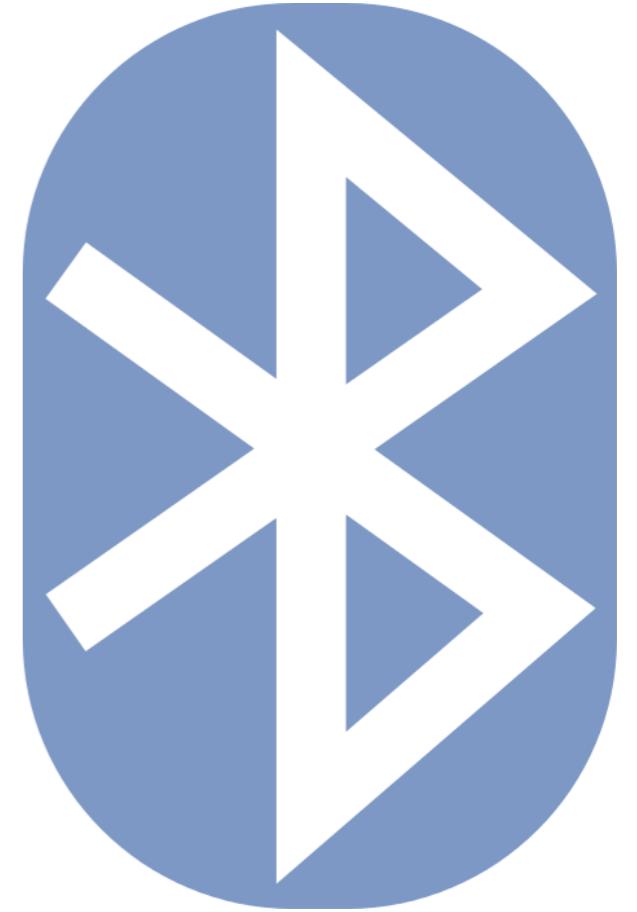
- Point-to-point
- tiny bandwidth
- tiny range, usually 10 cm or less
- limited applications
- very low cost
- operates worldwide at 13.56 MHz



# Bluetooth

---

- short range ~30 m, ubiquitous
- data rate up to 3 Mbps,
- pairing can be an issue
- profiles: headset, audio, serial, etc.
- requires a gateway to do Internet
- 2.4 GHz frequency hopping - worldwide okay



# 802.15.4

---

- inexpensive
- low bandwidth, low power
- medium range 30 m indoors, 2000 m outdoors
- point-to-multipoint
- interoperable, encryption available
- 2.4 GHz with some sub-Gig 868 & 900MHz, 250kb data rate



# Zigbee, Thread, Z-Wave

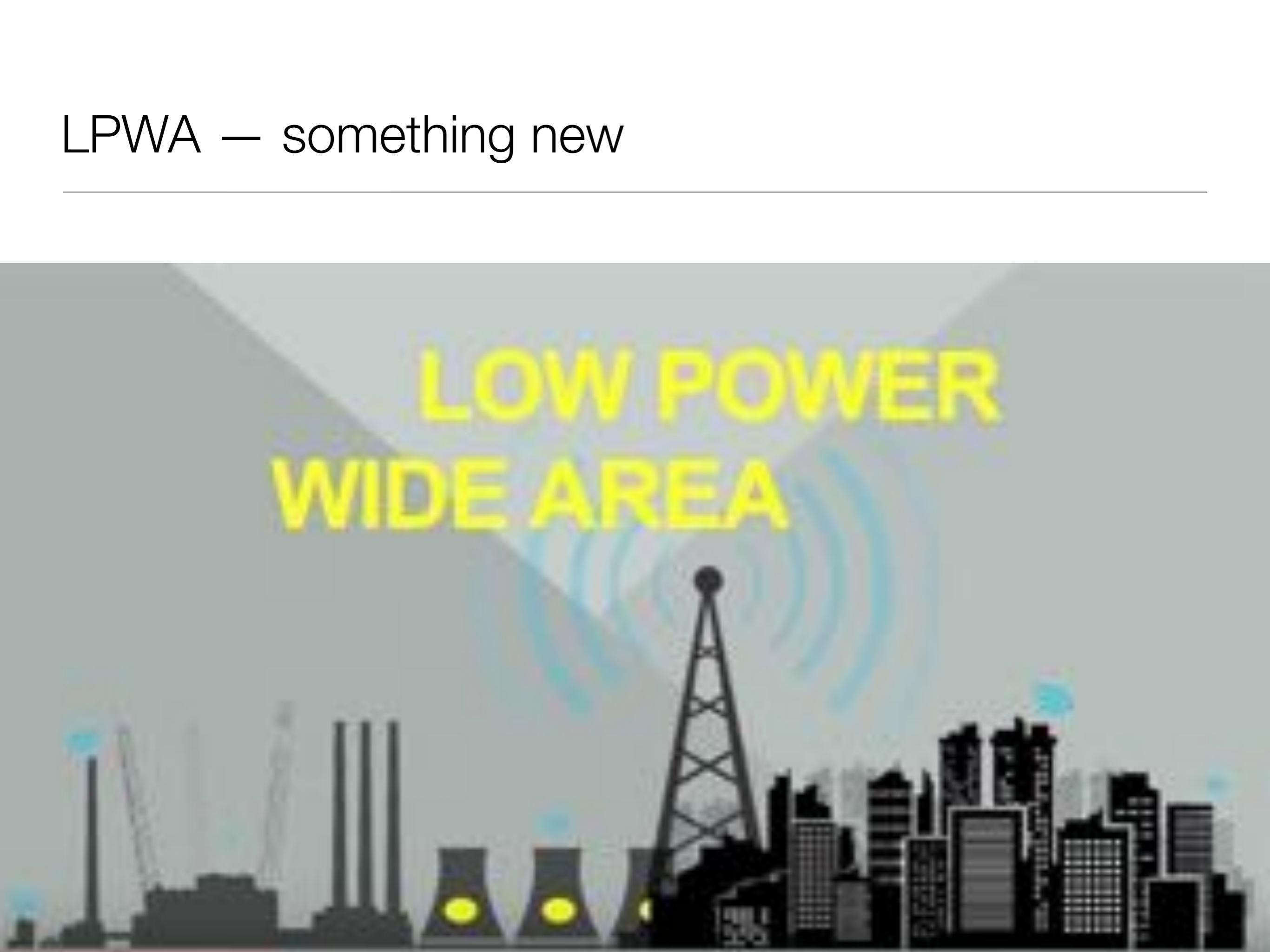
---

- 802.15.4 based
- adds mesh
- interoperable, encryption available
- designed for home-area networks
- 2.4 GHz for worldwide use
- modest bandwidth ~30 kb
- powered repeater nodes required



# LPWA – something new

---



LOW POWER  
WIDE AREA

# LoRa and LoRaWAN

---

- long range, low power
- 900 MHz in US, 868 Europe, 865 Asia
- Very low bandwidth to modest bandwidth
- Powered gateways required, service provider optional
- network server, infrastructure dependent
- 20 km range, or a few floors in a building



# 2G, 3G, 4G

---

- IP-ready
- very mobile
- service provider required
- can be quite expensive
- high power needs
- medium bandwidth



# Low-power LTE: CAT-M, NB-IoT

---

- worldwide coverage being built out
- service provider required
- dramatically lower costs
- excellent power management
- low bandwidth
- different frequencies, configs for different regions



# The Grand Master IoT Protocol

---

- everything has access to everything
- main thing holding IoT back?
- a distraction?



# Where to start

---

- Focus on your application
- Think about:
  - bandwidth, battery, location, data frequency, size, data costs, equipment costs, interoperation, certifications
  - What do you know? What just works for you?
  - Start small and simple, build in pieces, like with code





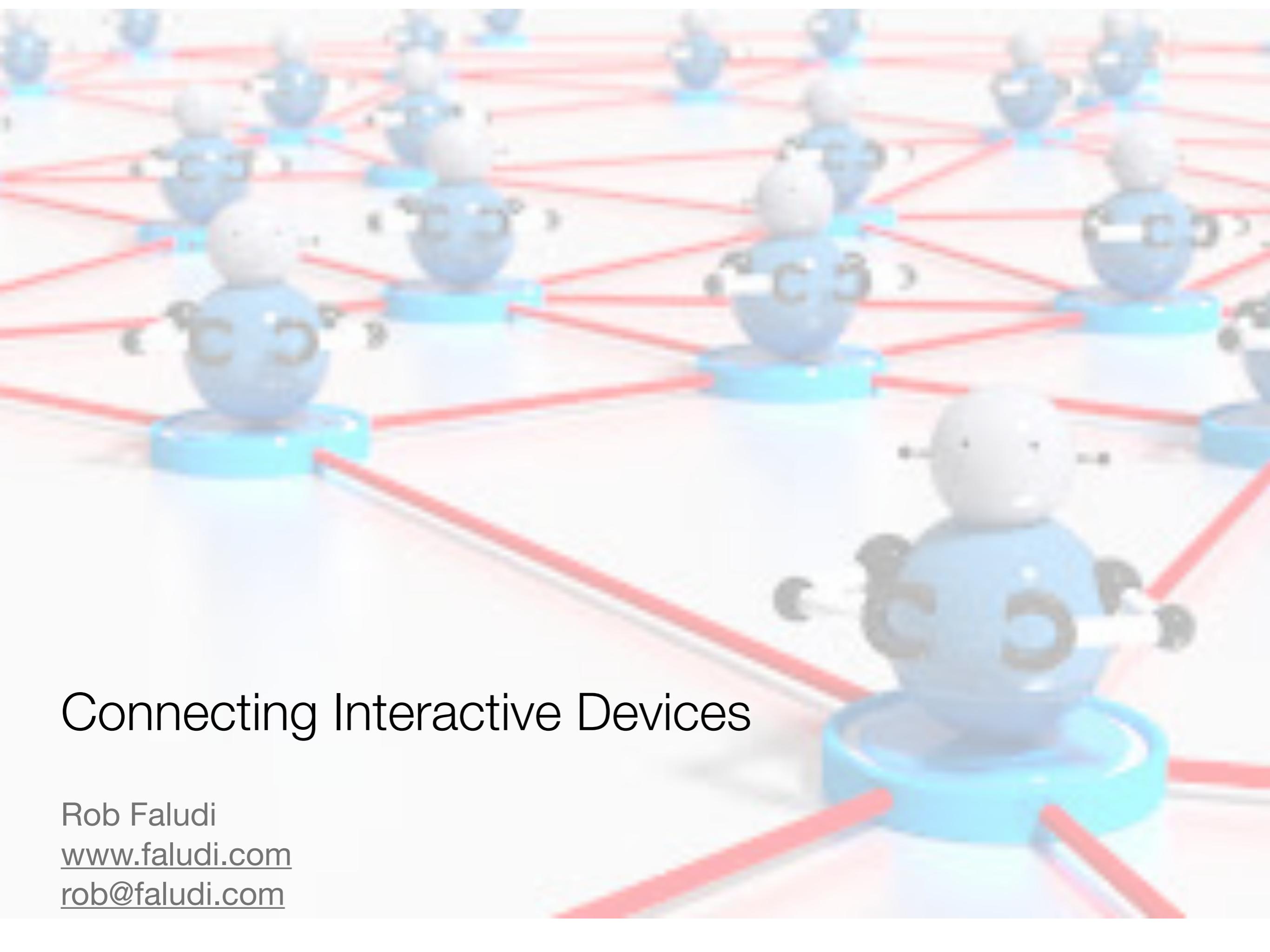
# Esper Domino

Jarashi Suki & IAMAS Ubiquitous Interaction Research Group  
wireless digital kinetic dominoes

# Esper Domino

---



A background image showing a complex network of red and blue wires or cables connecting various electronic components, such as microcontrollers and sensors, illustrating the interconnected nature of the devices being discussed.

# Connecting Interactive Devices

Rob Faludi

[www.faludi.com](http://www.faludi.com)

[rob@faludi.com](mailto:rob@faludi.com)