PRODUCT CHALLENGES FOR RETROFITTING THE WORLD WITH WIRELESS

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JANUARY 2018

2 OUTLINE

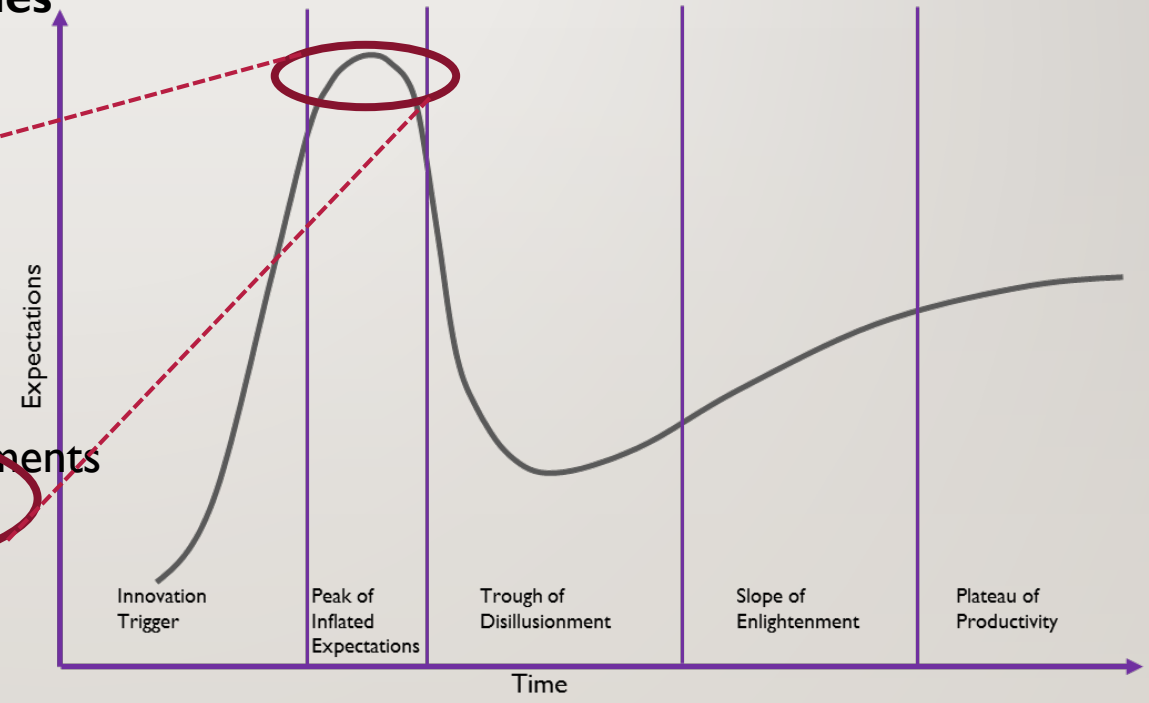
- Situation appraisal
- Problem statement
- Challenges
- Trends – helpful and not
- How do we make IoT roll out easy?
- Some specific implementation examples
- Conclusions/Suggestions

3 WHERE ARE WE?

IoT & Gartner Hype Cycle for Emerging Technologies

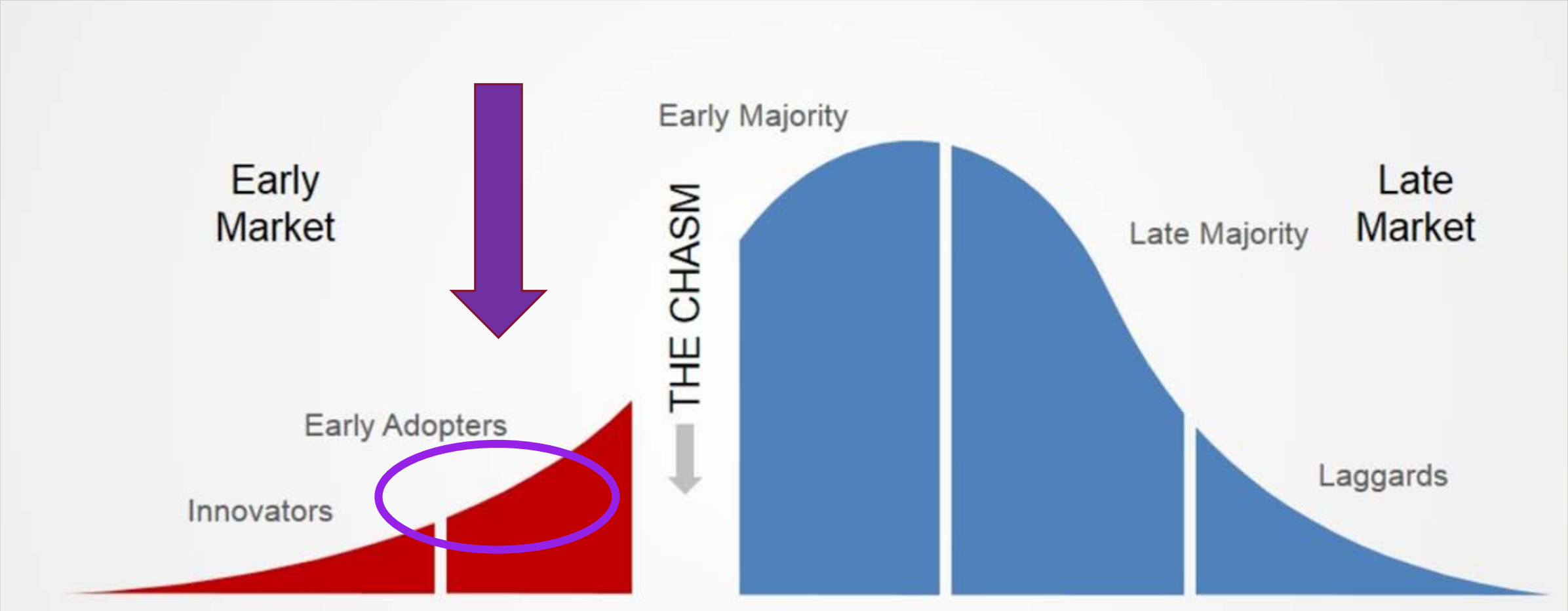
2014 – IoT at the peak
2015 – IoT at the peak
2016 – IoT platforms climbing,
- IoT integration entering trough
- Smart lighting at bottom of trough

2017 – IoT still at hype peak along with many required elements
IoT Security, IoT services, IoT Edge Architecture, LPWAN



Gartner's recent 2018 technology trends
IoT in Everything
"By 2020, IoT technology will be in 95% of electronics for new product designs. With the technology evolution surrounding the IoT, it will become increasingly possible to add IoT features to a product at minimal cost".

4 WHERE ARE WE?



5 WHERE IS IoT GOING?

- When the first popular browser (Mosaic) came out in in 1993 could you predict:
  - YouTube?
  - Amazon?
  - Facebook?

UNLIKELY

- Hypothesis: We do not really know where the Internet of Things is going, but trends tend to stay in motion – until they break
- We will consider some known trends and issues to see where the issues may be pointing

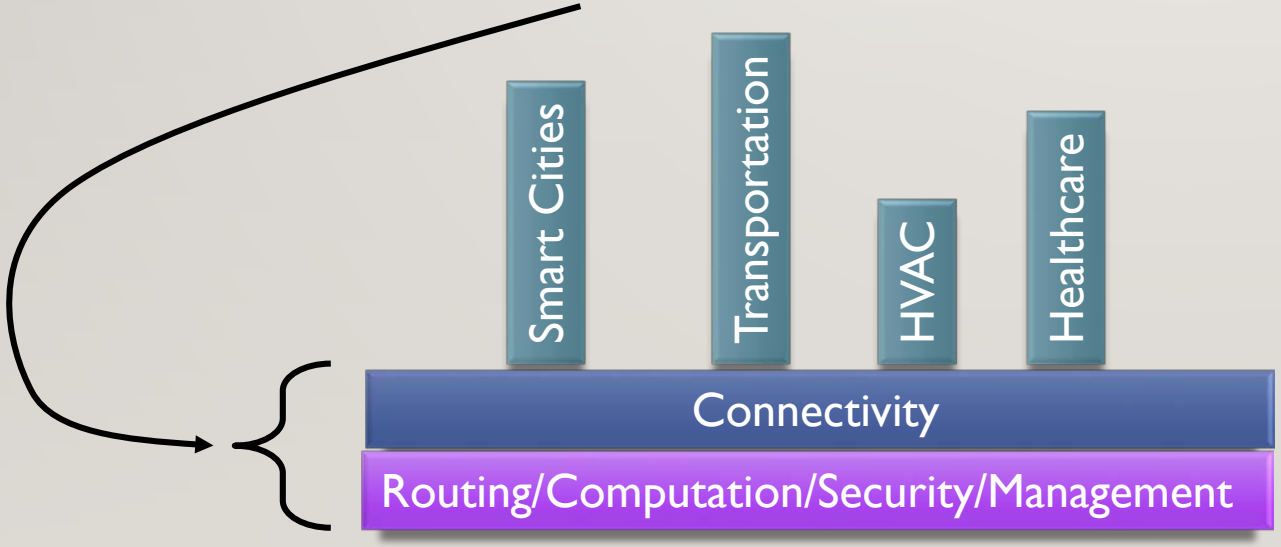
6 PROBLEM STATEMENT

BUSINESS OBJECTIVE

- Capture the targeted benefits of the Internet of Things without replacing all capital equipment in existence.

IoT INDUSTRY TECHNICAL OBJECTIVE

- Create a horizontal platform to enable a wide ranges of IoT applications



A robust (near) ubiquitous platform reduces cost of follower applications

$n \cdot \mathrm{Log}(n)$ per Metcalf?

PROBLEM STATEMENT cont'd

IoT-ENABLED DEVICE REQUIREMENTS

- Sensor
- Actuator (optional)
- Computation capability to transform data and/or interpret the operational environment
- Power
- IP communications capability
  - Wireless module
  - Antenna
- Ideally, support IoT platform expansion

We will focus on wireless devices

8 CHALLENGES

1. Wireless was not in the plan when existing equipment was installed
   - Antenna placement
   - Propagation environment unplanned
2. Additional power may not be readily available or usable
   - DC vs. AC, portable devices, wiring locations, etc.
3. Sensor and transceiver attachment
4. Variable data needs with time and operational scenario
   - Normal operation vs security patches
   - New use cases added over time

9 CHALLENGES cont'd

5. Point/targeted solutions superior for any specific application
   - Conflicts with IoT industry mix-and-match solutions
6. => The first large applications will drive the formation and history of IoT
   - Ideal if we can build horizontal platform from first deployed verticals
7. Maintenance costs need to be low

10 LONG TERM TRENDS

1. Moore's Law
2. Dominance of software
3. Evolving wireless standards
4. More sensors
5. H/W CAPEX trending downward
6. X As A Service growing
7. Self-service world
8. Cybercrime
9. Smaller is better
10. Laws of physics are immutable

1. Gates are "free". Waste them to get benefits.
2. Only use hardware when you must.
3. See item 2.
4. Labor to retrofit sensors must be modest.
5. Driven by global competition and1 & 2 above
6. Remote management required
7. Easy installation, maintenance & upgrading required
8. Accommodation of security updates
9. Less antenna area
10. Link budget trade offs as shrink devices

ROLLING OUT THE INTERNET OF THINGS HOW DO WE MAKE RETROFITTING EASY?

- Use existing application personnel
  - IoT is a system enhancer. I.E. an additional thing for the existing field staff to handle
- Multi-standard devices
  - SDR & ACM – radio (re)configures to application data needs and local wireless links and environment
- Leverage off other activities to build infrastructure
  - Cellular LTE - upgrades driven by smart phones and streaming data needs
  - Smart city - driven by easy savings from lighting upgrades
  - Home – replacing AP's regularly (carrier churn or new toys)
- Robustness
  - IoT gear ideally not the driver of field visits
  - Architectural redundancy

SDR – software defined radio
ACM – adaptive coding and modulation

MIX & MATCH VS. POINT SOLUTIONS

MIX & MATCH

- Vendor covers wide application range
- Sub-optimal application solution
  - Can be awkward retrofit
  - Unused elements in most applications
- Suitable for high-touch custom solutions

POINT SOLUTIONS

- Narrow application domain
- Optimal solution
  - Designed to fit existing eco system
  - Few extraneous pieces
- Need sufficient volume to justify

- Design often starts with the single board computer

- Design starts with existing working equipment

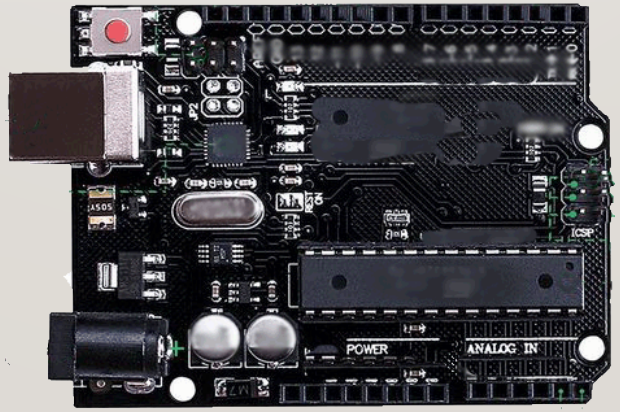
MIX AND MATCH PRODUCTS

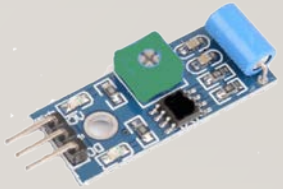
- Mix & match product families
  - Single board computers
  - Several common communications interfaces
    - USB, Ethernet,
  - Selectable wireless modules
    - Short range RF to cellular
  - Standard APIs
- No common form factors
- Various power sources
- Ad hoc sensor attachment

These are good products coming from reliable suppliers and manufacturers

BUT

products cannot have both broad application and be application optimized.





APPLICATION DRIVEN vs MIX and MATCH
Vibration

Point Solution

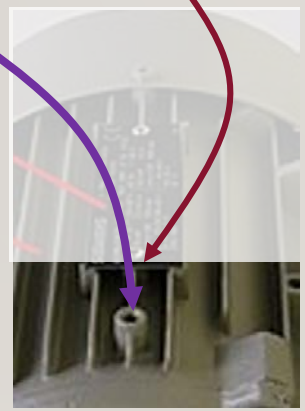
Starts from existing solution perspective

ISM band
Wireless module

Vibration sensor

Adapter bolt

Mounting thread



Focuses on physical issues first

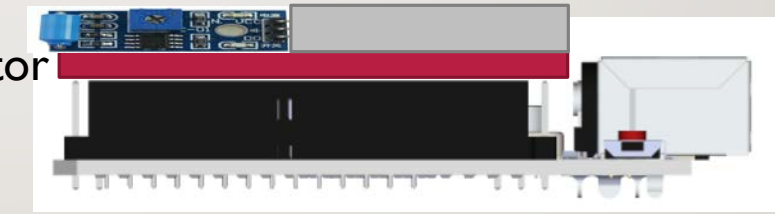
Mix & Match Solution

Starts from IoT perspective

Vibration Sensor

Wireless Module

Adaptor

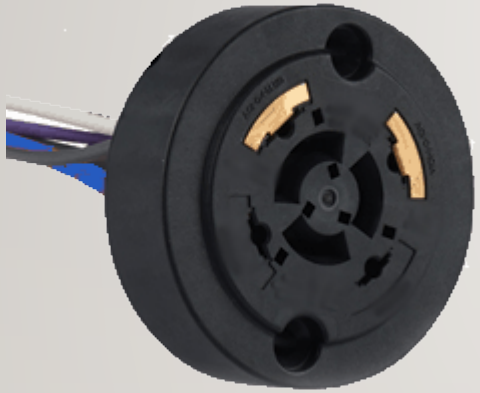


Single Board Compute

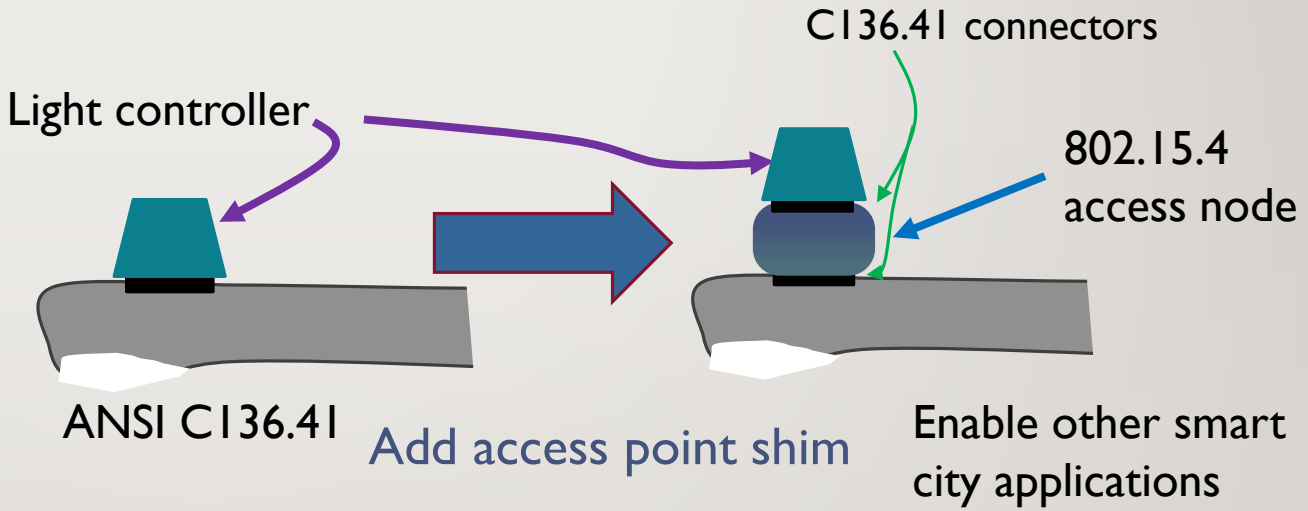
IoT family pieces play well, but need current loop or other cabled interface to sensor.

APPLICATION-DRIVEN & ADDING INFRASTRUCTURE

Lighting infrastructure with ANSI C136.41



Extend existing standard lighting control connector



Lighting is omnipresent:
street, office, factory, house

E.g. North Vancouver, BC municipality requires 7 pin dimmer interface on LED lighting as way to support future Smart City wireless infrastructure.

16 INSTALLATION AND MAINTENANCE ENVIRONMENT SMARTPHONES VS IoT DEVICES

Smart Phone

- Monthly bill $50 - $60
- Always a human nearby
- Large data pipe for s/w upgrades
- Ample power (Daily charging)
- Large community of users (friends)
- Upgrade every 3 years

Typical IoT Sensor Device

- Monthly bill $0.25 - $5.00
- Humans optional
- Small data pipe for f/w upgrades
- (Lifetime?) battery
- Specialized operation
- Installed for long period

IMPROVING IoT CONNECTIVITY RELIABILITY

Internet/Architecture Approach	Product Quality Approach	Adaptable/Upgradable

• Reliability built into the architecture that allows devices to fail
• Over provision wireless resources
	• Industrial grade parts
	• Burn in
	• Environmental control
	  • Conformal coating,
	  • Thermal moderation (heat sinks & heat pipes)
		• Feature upgrades
		• H/W work arounds
		• Device-internal redundancy

SECURITY UPDATES

- Consider battery powered Sigfox device
  - 140 uplink messages/day @ 12 bytes => 613 kBytes / yr
  - 4 downlink @ 8 bytes => 11.7 kB / yr
- Consider a 500 kB security related firmware update
  - Broadcast downlink helps a lot, but each device needs complete checksum verification & handshakes to enable updates.
  - Receive power ≈ 15% of TX consumption + ACKs & OH => 20%
    - => each update ≈ 2 months of power

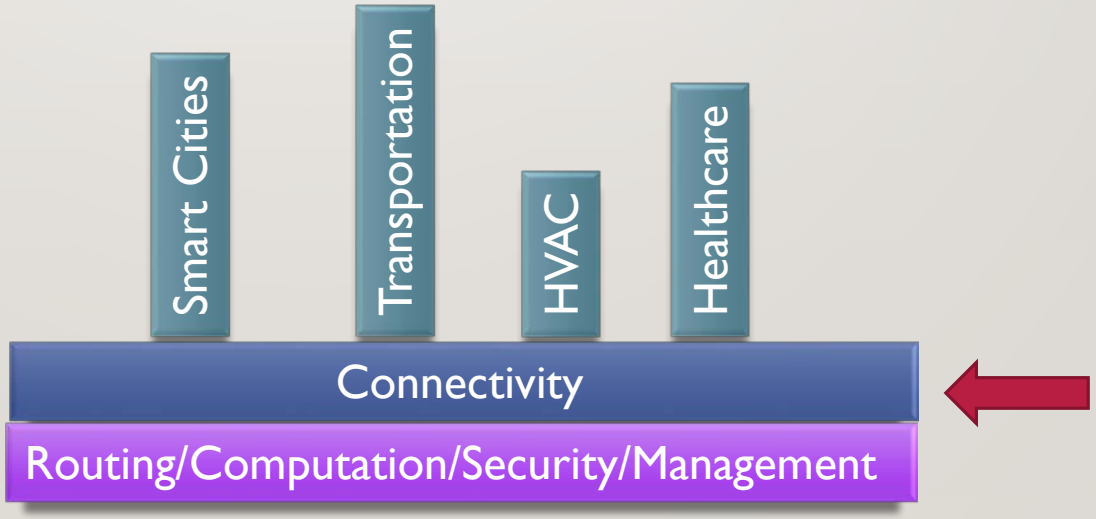
CONNECTIVITY INFRASTRUCTURE

REPURPOSE or EXPAND

- Street lighting
- Indoor lighting
- AC power system
  - PLC
  - Smart meter
- Cellular system
- Home Wi-Fi router
- SATCOM
  - VSAT

NEW BUILDS

- LPWAN
- SATCOM
  - LEOS



Likely high runners

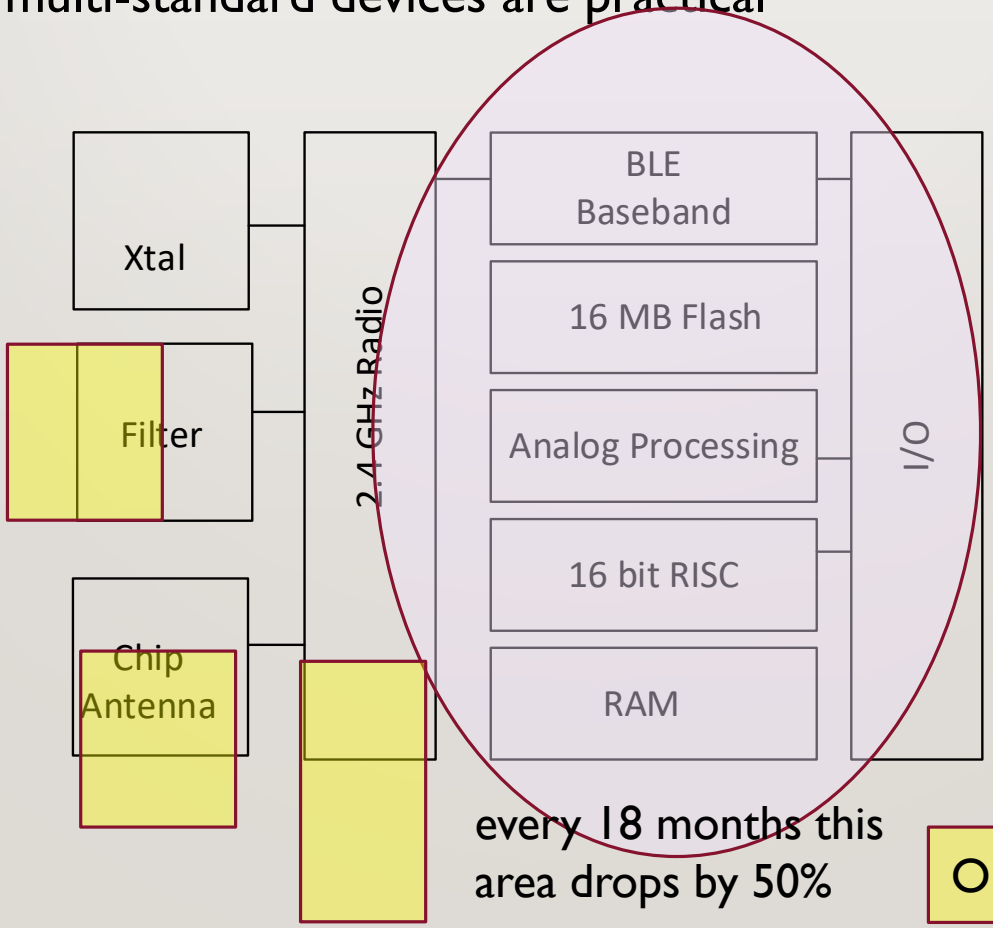
ANTENNA SIZE ISSUES

- Antenna Sizes - Chu-Harrington limit $Q \geq \frac{1}{k^3 a^3} + \frac{1}{ka}$ where: $k = \frac{2\pi}{\lambda}$
  a = radius of containing sphere
- Shrinking passive antennas => $Q \uparrow$ => Bandwidth ↓ and/or η ↓
  => bit rate, range and/or battery life ↓
- Possible solutions:
  - Higher frequencies
    - A current trend
    - OK for short links
    - Technology issue WRT device cost and efficiency
  - Active antennas
    - Multiple connection points
    - Beam steering
    - Diversity

    } New standard interface? More than 50 Ω coax needed
  - Mechanically coupled radiators (electrets, magnetic or piezo electric designs)?
    - Utility TBD. Wild card

WIRELESS FLEXIBILITY

- Multiband and multi-standard devices are practical



every 18 months this area drops by 50%

Order Mag growth for dual mode

22 SOME IDEAS TO EASE CROSSING THE CHASM

1. Wireless flexibility (SDR & ACM) in end devices
   - Waste gates as cost is small and keeps shrinking
   - Inter-standard negotiation needed – IEEE-SA work item?
2. Access technology discovery by end devices
3. Deployment of existing ecosystem wireless access points
   - Street lighting mounted APs – extension of smart lighting installation for Smart City
   - WiFi APs that also support 802.15.4 and other low-rate ISM band technologies
   - Cellular
4. Design IoT devices from the traditional application end, not the single-board computer
5. Small active antennas – maybe a standard interface for same

Thank you for listening

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