MACHINE-TO-MACHINE OR THE INTERNET OF THINGS

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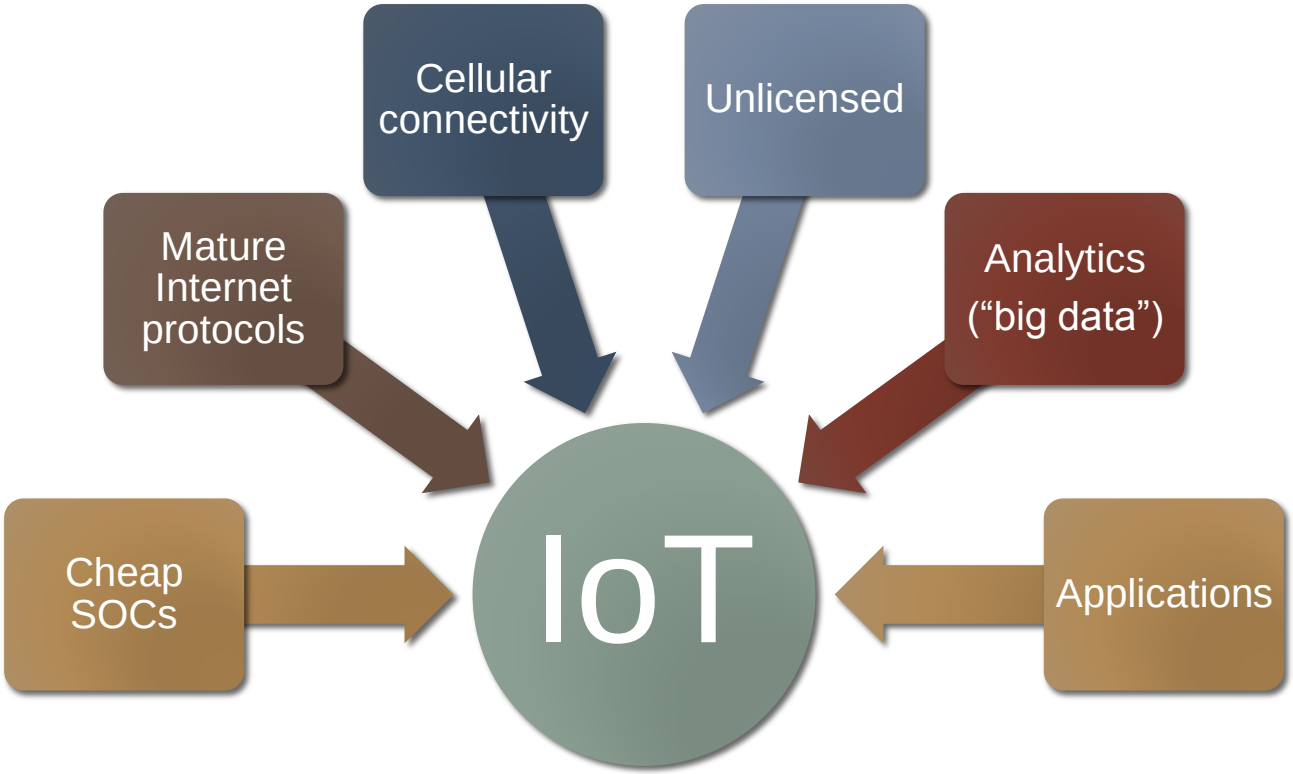
with slides from Harish Viswanathan, Alcatel-Lucent

Overview

- M2M: more than cellular or unlicensed
- Technical challenges for M2M
- Spectrum – the lifeblood of M2M
- Columbia U. research examples:
  - SECE: unifying diverse networks into a user-programmable system
  - EnHANTS: environment-powered nodes

Key enablers



M2M is not…

- does not always uses cellular networks
- is not always energy-constrained
- is not always cost-constrained
- only uses puny microcontrollers
- is not always run by large organizations
  - many small & mid-sized providers
  - usually embedded into other products

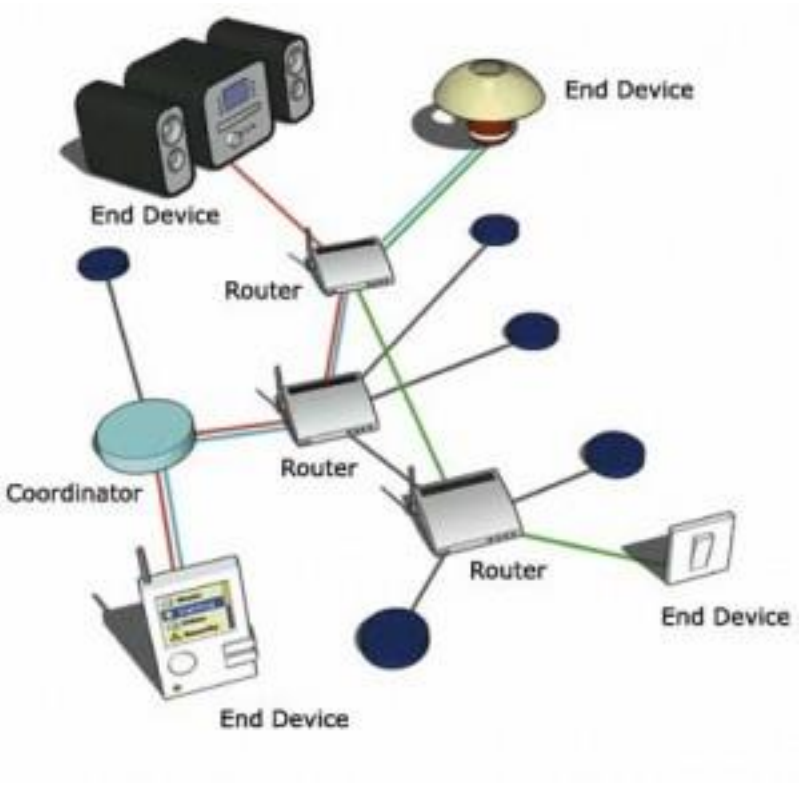
M2M varies in communication needs

sensors

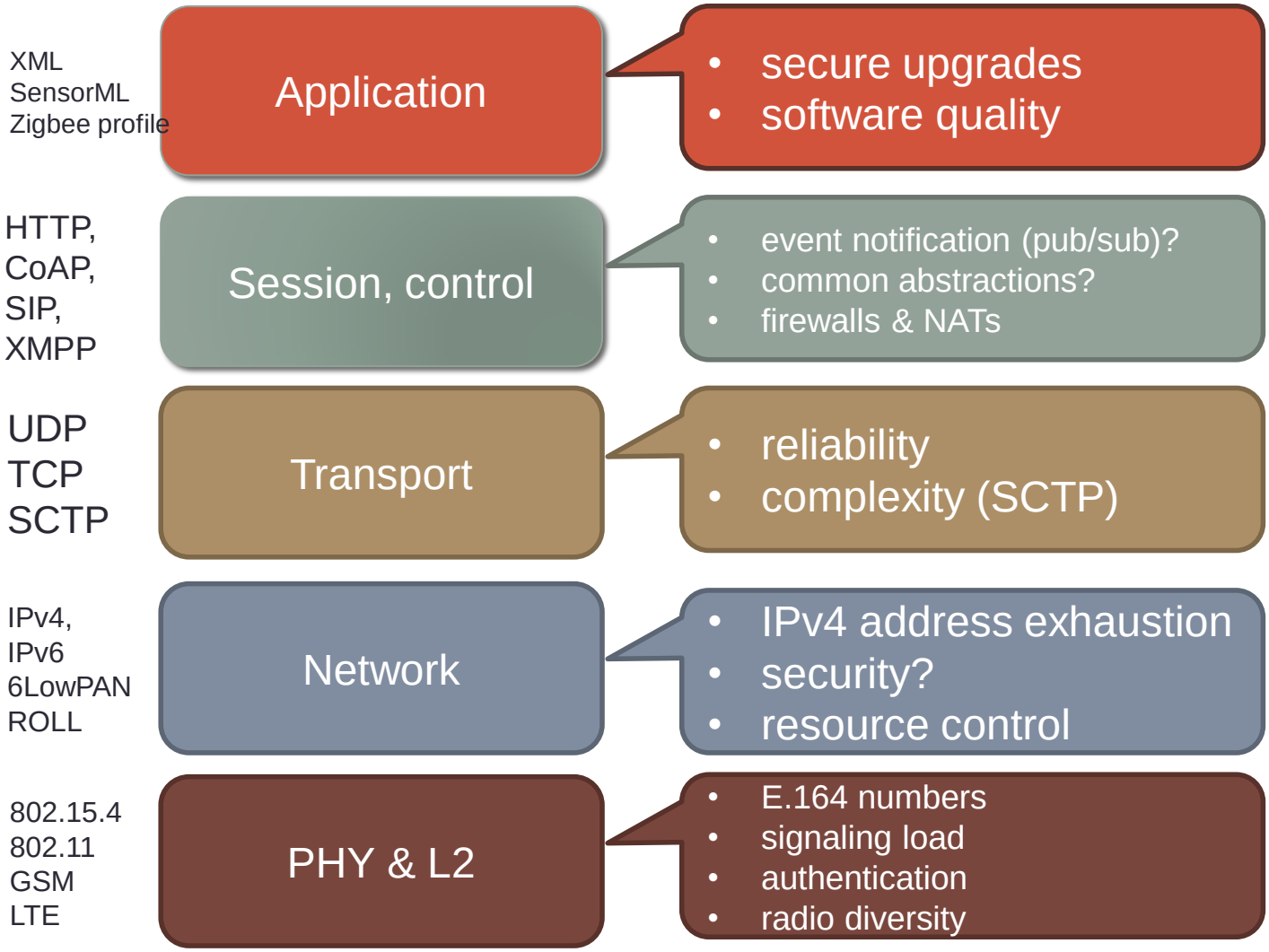
1/hour | 1/minute | 1/second | 10/second

actuators

Not just cellular *or* unlicensed

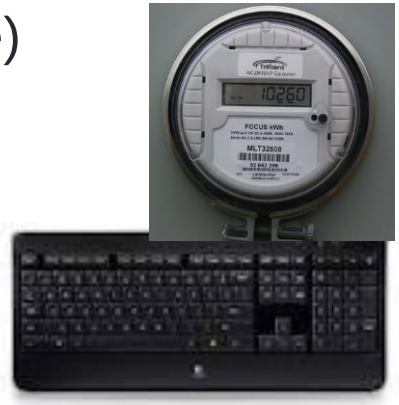


Technical challenges



Network challenges

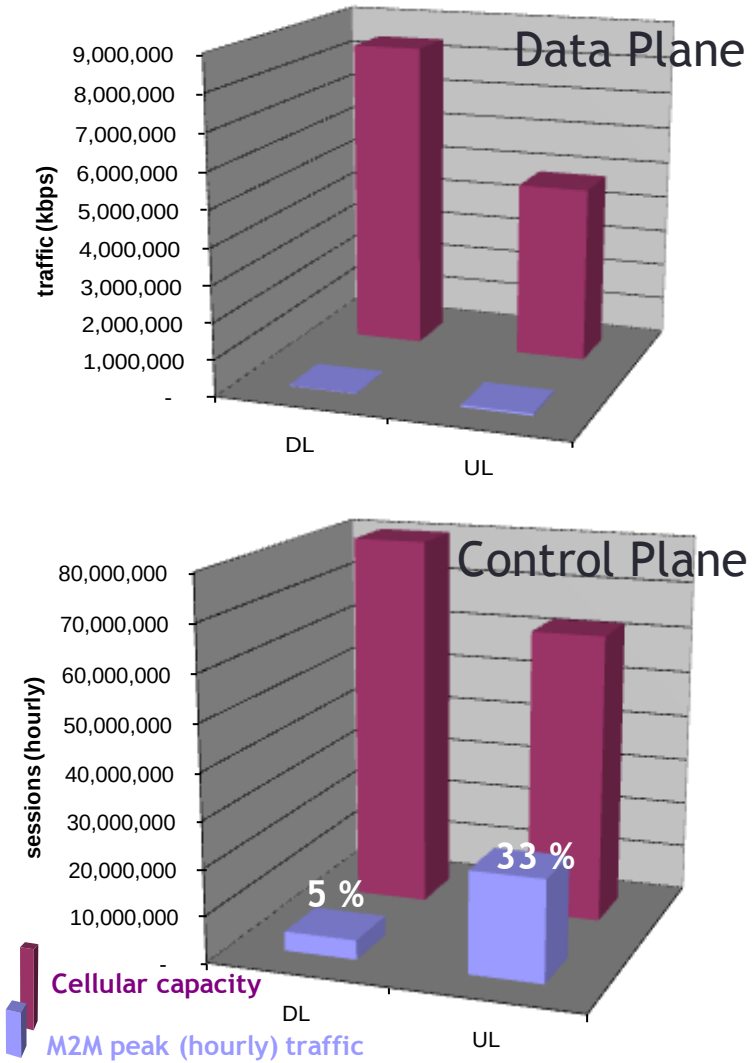
- Unlicensed
  - How do I attach and authenticate a device to a (home) network?
  - Credentials?
- Licensed
  - Reliability → multiple *simultaneous* providers
  - Mobility → different providers in different regions
  - Charging → often low, intermittent usage, sometimes deferrable ("Whispernet")
    - From $50/device/month → < $1/month?
- Authentication
  - Which devices can be used by whom and how?
    - "Any employee can monitor the room temperature in any public space, but only Facilities staff can change it"



Signaling increases 30-50% faster than data

- Isolate M2M traffic from regular traffic
- Flexible scaling requirements because of bulk contracts
- Signaling traffic management
- Low Power, short payloads, bursty traffic
- Low cost but also low performance requirements
- In network monitoring

M2M traffic modeling shows disproportionately large signaling



< 1% of data plane capacity is consumed by M2M but more than 30% of signaling capacity is consumed

Harish Viswanathan, Alcatel-Lucent, 2012

FCC TAC preliminary recommendations

- R1: Additional M2M unlicensed band (1.2 – 1.4, 2.7 – 3.1 GHz)
- R2: M2M service registration
- *R3: Numbering and addressing plan*
  - IPv4 → IPv6
- R4: M2M center-of-excellence at FCC
- R5: Certification lite
- *R6: 2G sunset roadmap*
  - 2G re-farming, security issues → LTE with IPv6
- R7: Encourage 3G/4G module building

Recommendation 3: Create a numbering and addressing plan

- Situation
  - Currently there are tens of millions of devices latched onto 2G networks with IPv4 addresses in place. As IPv4 approaches depletion, the M2M ecosystem will be looking for a solution for a new addressing schemes for the millions of additional devices scheduled to hit the market.
- Complication
  - A solution is required soon before Carriers decide on their own proprietary solution making it even more complicated for M2M devices to be introduced in the market and have broad acceptance across carriers.
- Recommendation
  - Develop an IPv6 migration path for the near, medium, and long term to meet requirements for M2M fixed and mobile applications (On-Net, Off-Net (i.e. Roaming).
- Complexity to Implement
  - Medium Term

Recommendation 6: Create a 2G sunset roadmap for migration to 3G / 4G

- Situation
  - National carriers have announced that they will be shutting down 2G existing wireless networks in the coming years. Some will be shut down as soon as 2016.
- Complication
  - Since there are tens of millions of 2G devices connected to these networks, existing devices will be forced to upgrade to 3G/4G modules. This will have a significant impact on the ROI for device manufactures who will be required to upgrade current device set. For many M2M players the 2G module prices have finally hit a point where they are seeing ROI (~$20.00 per module). The module prices for 3G/4G prices are double and quadruple (~$40.00 to ~$80.00) in some cases.
- Recommendation
  - Create a 2G roadmap for transitioning from 2G to 3G/4G. This will allow current M2M 2G device OEMs to plan accordingly.
  - FCC recommended window of time supporting legacy 2G infrastructure with migration guidance to LTE with IPv6 addressing. The desired result being to return spectrum while upgrading infrastructure, eliminating legacy.
- Complexity to Implement
  - Medium Term

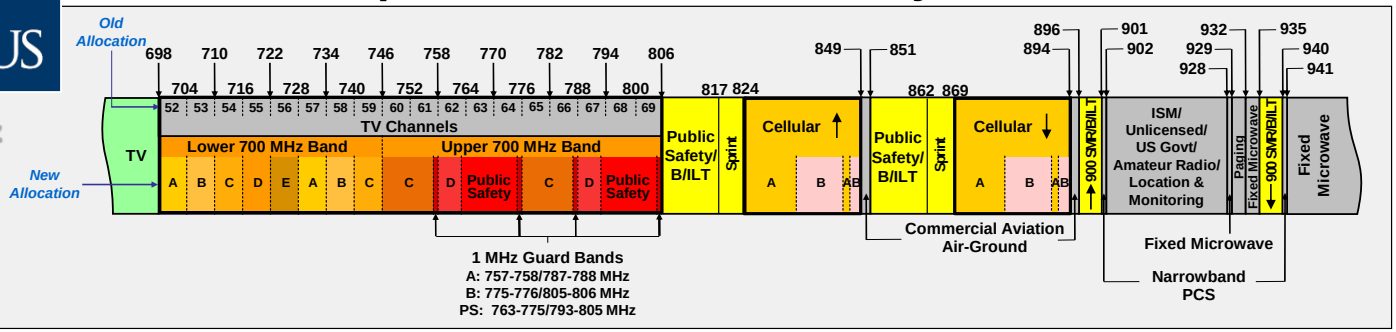
cellular = about 500 MHz in total

STIFEL NICOLAUS

U.S. Spectrum Allocation of Key Bands

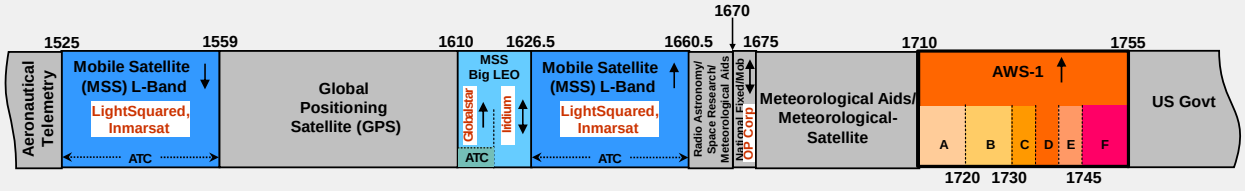
July 14, 2011

700 - 1000 MHz



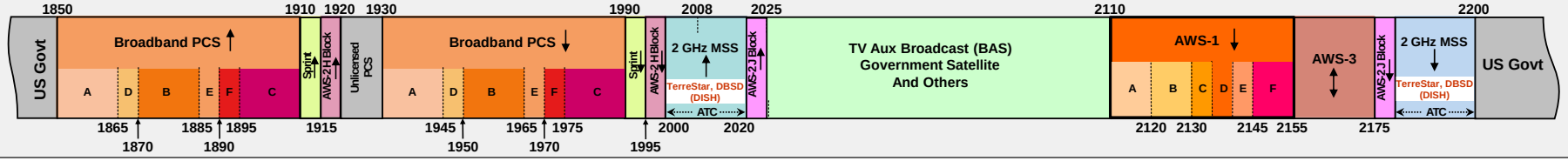
IEEE Standard Band Designators	
HF	3-30 MHz
VHF	30-300 MHz
UHF	300-1000 MHz
L band	1-2 GHz
S band	2-4 GHz
C band	4-8 GHz
X band	8-12 GHz
Ku band	12-18 GHz
K band	18-27 GHZ
Ka band	27-40 GHz
V band	40-75 GHz
W band	75-110 GHz
mm wave	110-300 GHz

1500 - 1800 MHz

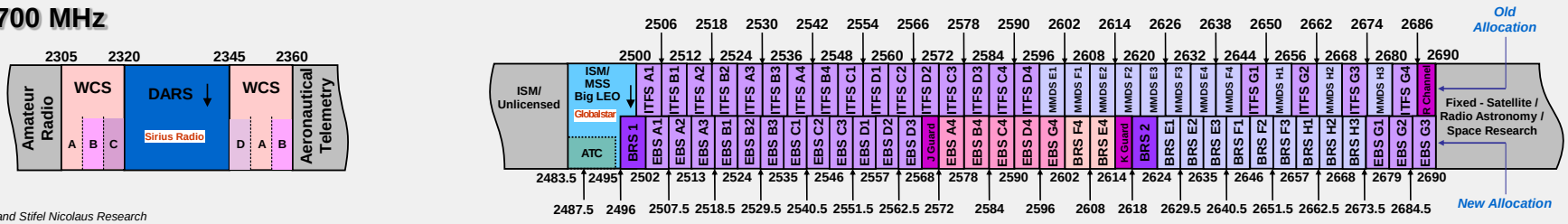


Legend
- Uplink Band
- Downlink Band
- TDD Band

1800 - 2200 MHz



2300 - 2700 MHz



Source: FCC, Sprint and Stifel Nicolaus Research

From beachfront spectrum to brownfield spectrum

no interference!
guard bands!

From empty back yard to time share condo

high tower, high power
2G

small cells
4G
DSA

Don’t be a resource hog!

- 2 G spectrum waste
  - 0.17 b/s/Hz vs. >= 2 b/s/Hz for 4G
- E.164 numbering
  - 500 numbers (PCS)
  - one new area code a year!
- Shared & scarce public resources

Spectral efficiency

- b/s/Hz: modulation, FEC, MIMO, …
- but also total spectral efficiency
  - guard bands
  - restrictions on adjacent channel usage
  - “high power, high tower” → small cells → higher b/s/Hz
- data efficiency
  - e.g., H.264 is twice as good as MPEG-2/ATSC
  - and H.265 twice as good as H.264
- distribution efficiency
  - unicast vs. multicast
- protocol efficiency
  - avoid polling → need server mode
- mode efficiency
  - caching
  - side loading
  - pre-loading

Current unlicensed spectrum

Frequency range		Bandwidth	Center frequency	Availability
6.765 MHz	6.795 MHz	30 KHz	6.780 MHz	Subject to local acceptance
13.553 MHz	13.567 MHz	14 KHz	13.560 MHz	
26.957 MHz	27.283 MHz	326 KHz	27.120 MHz	
40.660 MHz	40.700 MHz	40 KHz	40.680 MHz	
433.050 MHz	434.790 MHz	1.84 MHz	433.920 MHz	Region 1 only and subject to local acceptance
902.000 MHz	928.000 MHz	26 MHz	915.000 MHz	Region 2 only
2.400 GHz	2.500 GHz	100 MHz	2.450 GHz	
5.725 GHz	5.875 GHz	150 MHz	5.800 GHz	
24.000 GHz	24.250 GHz	250 MHz	24.125 GHz	
61.000 GHz	61.500 GHz	500 MHz	61.250 GHz	Subject to local acceptance
122.000 GHz	123.000 GHz	1 GHz	122.500 GHz	Subject to local acceptance
244.000 GHz	246.000 GHz	2 GHz	245.000 GHz	Subject to local acceptance

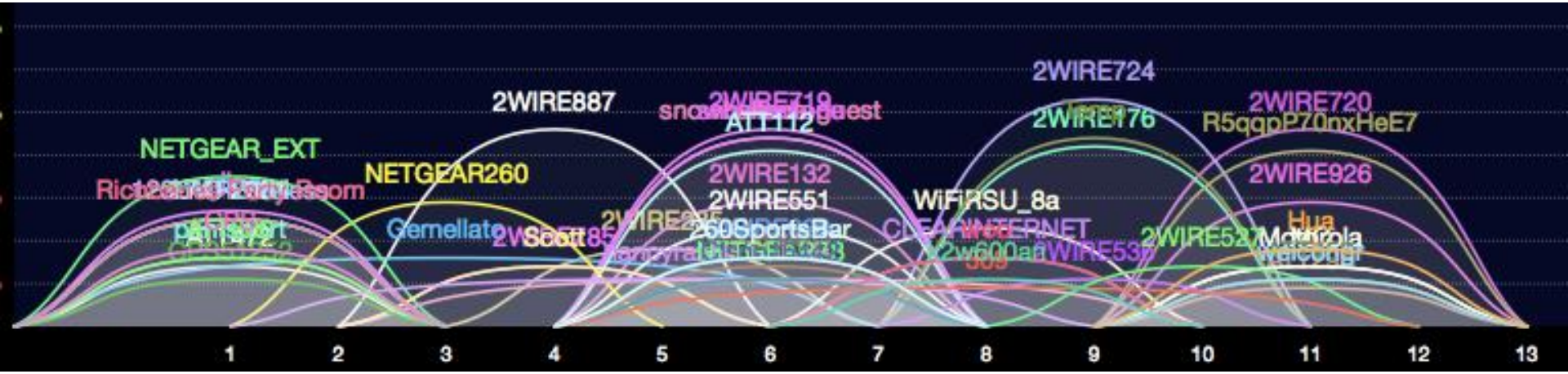
+ TV white spaces (in 476-692 MHz range) – availability varies

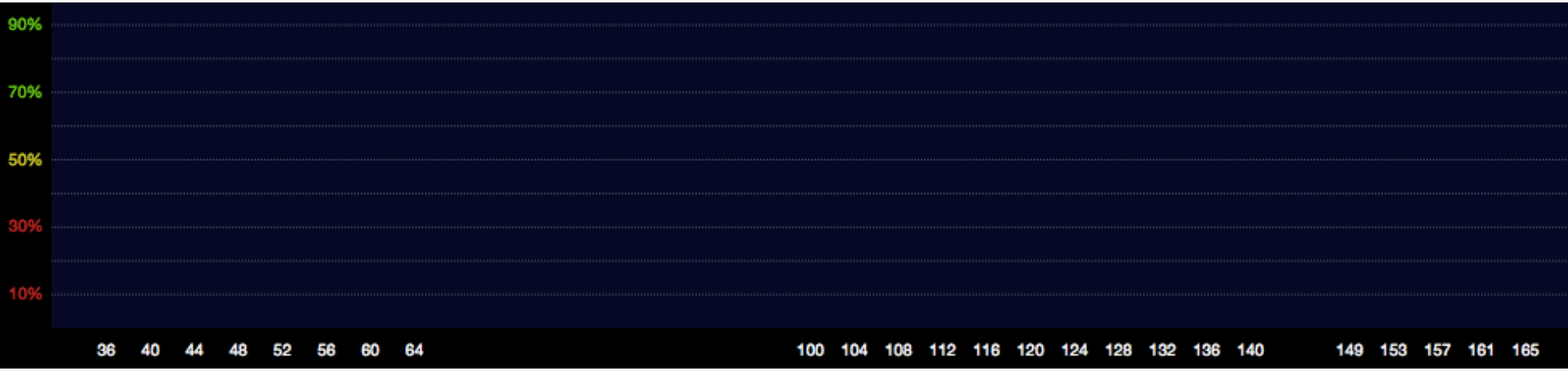
FCC actions for (M2M) spectrum

- More than 300 MHz of additional spectrum in pipeline
- Encourage unlicensed & lightly-licensed spectrum
  - TV white spaces (600 MHz) → geographical databases
  - 3.5 GHz “small cells” (3550-3700 MHz), 200 mW (1 W EIRP)
  - 4.9 GHz (20 dBm/MHz)
  - incentive auction guard bands as new unlicensed UHF spectrum (600 MHz)
- Experimental licensing revision
- Medical body area networks: 2360 – 2400 MHz

WiFi Explorer

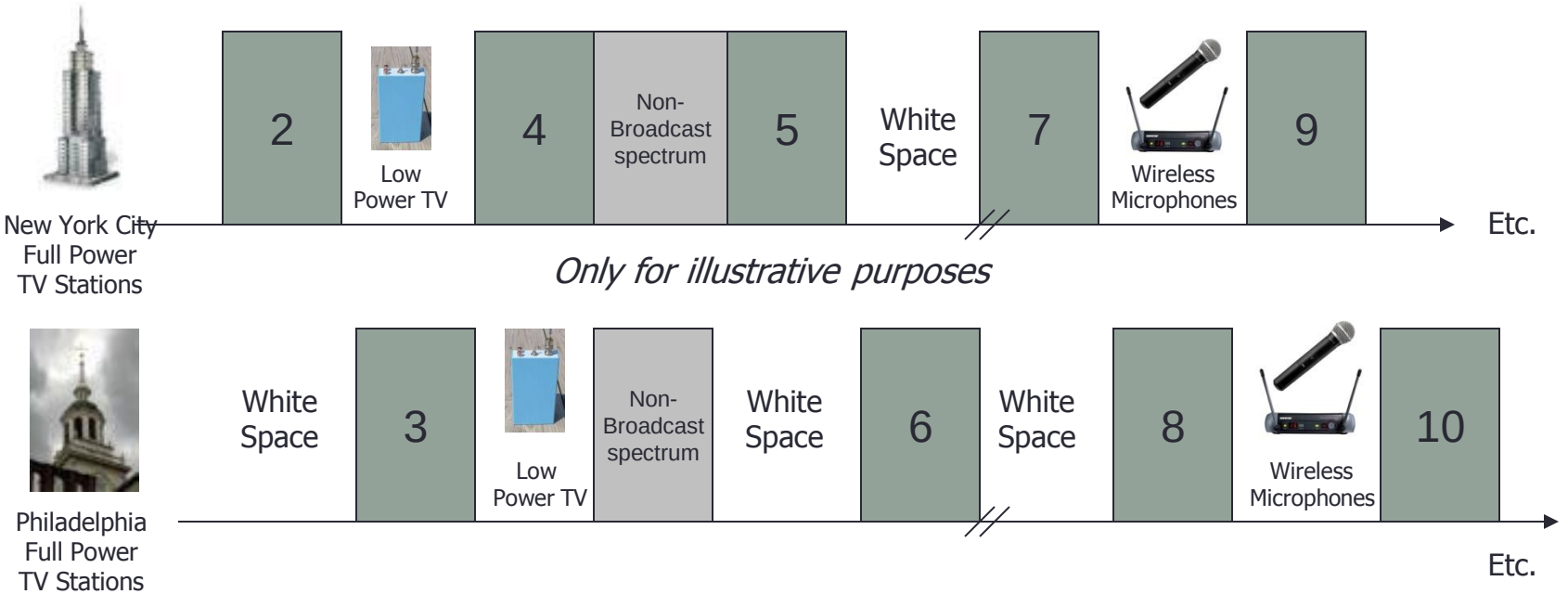
2.4 vs. 5.8 GHz





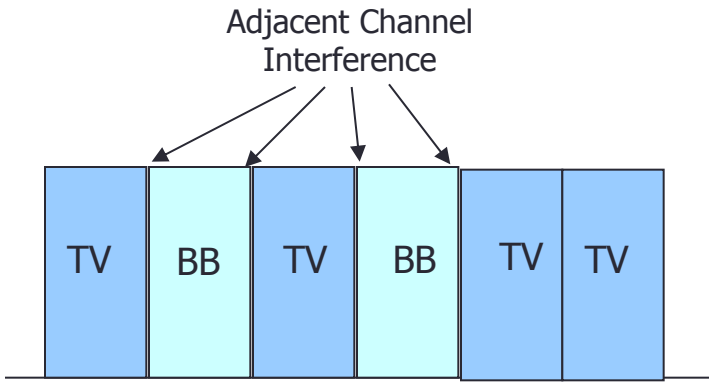
TV white spaces

- TV channels are “allotted” to cities to serve the local area
- Other licensed and unlicensed services are also in TV bands
- “White Spaces” are the channels that are “unused” at any given location by licensed devices

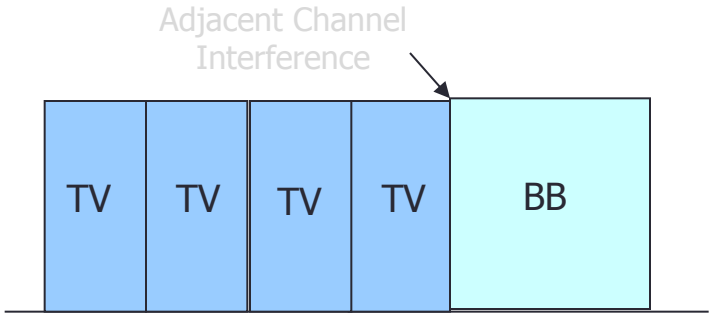


Freeing spectrum: incentive auctions

- Incentive auctions will share auction proceeds with the current occupant to motivate voluntary relocation of incumbents
  - Otherwise, no incentive for current occupant to give back spectrum
  - Stations keep current channel numbers
    - via DTV map

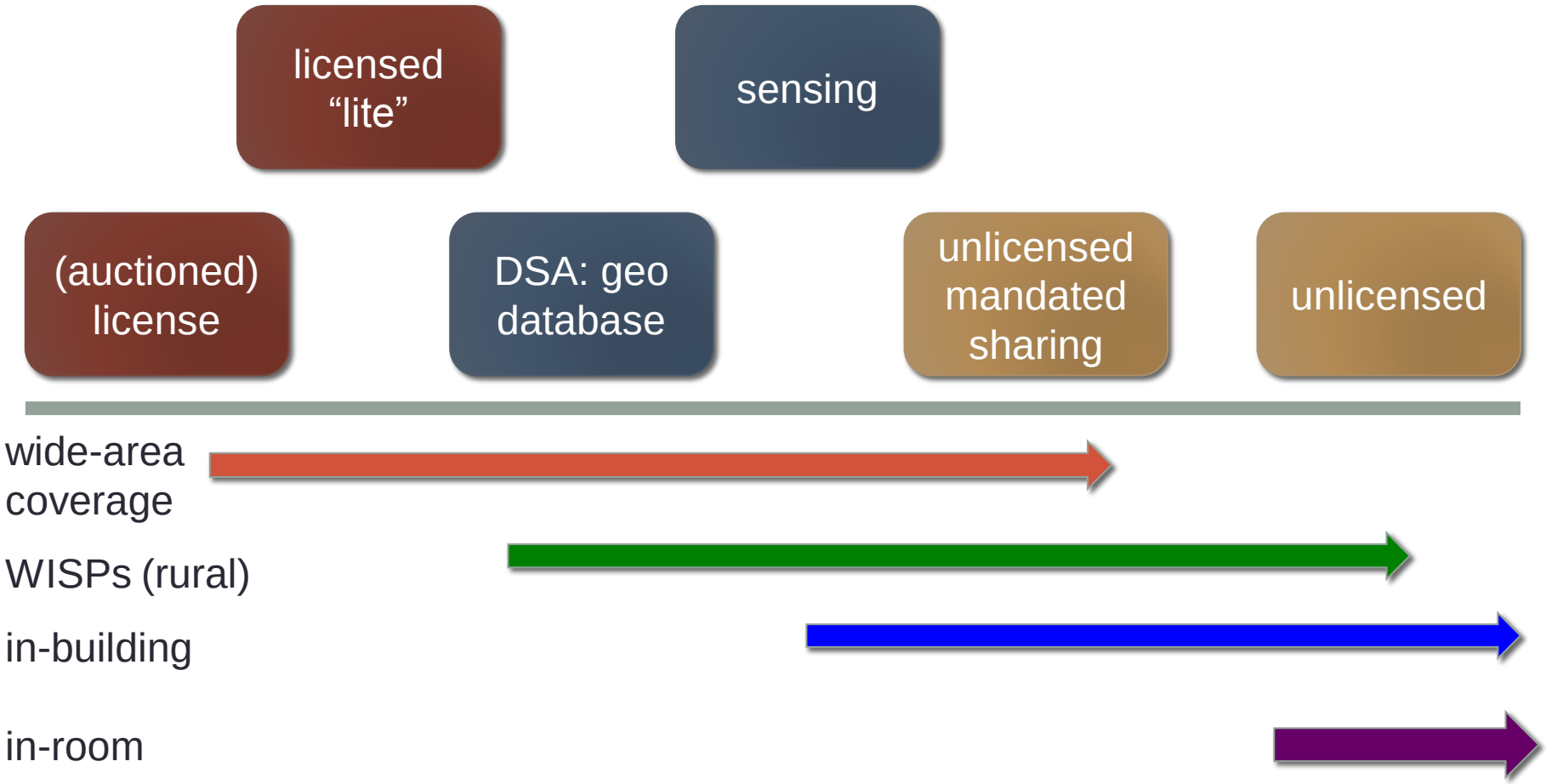


Without Realignment:
Reduced Broadband Bandwidth



With Realignment: Accommodates Increased Broadband Bandwidth

Spectrum tool kit



Extreme M2M: self-powered devices

Leviton WSS0S - Remote Switch

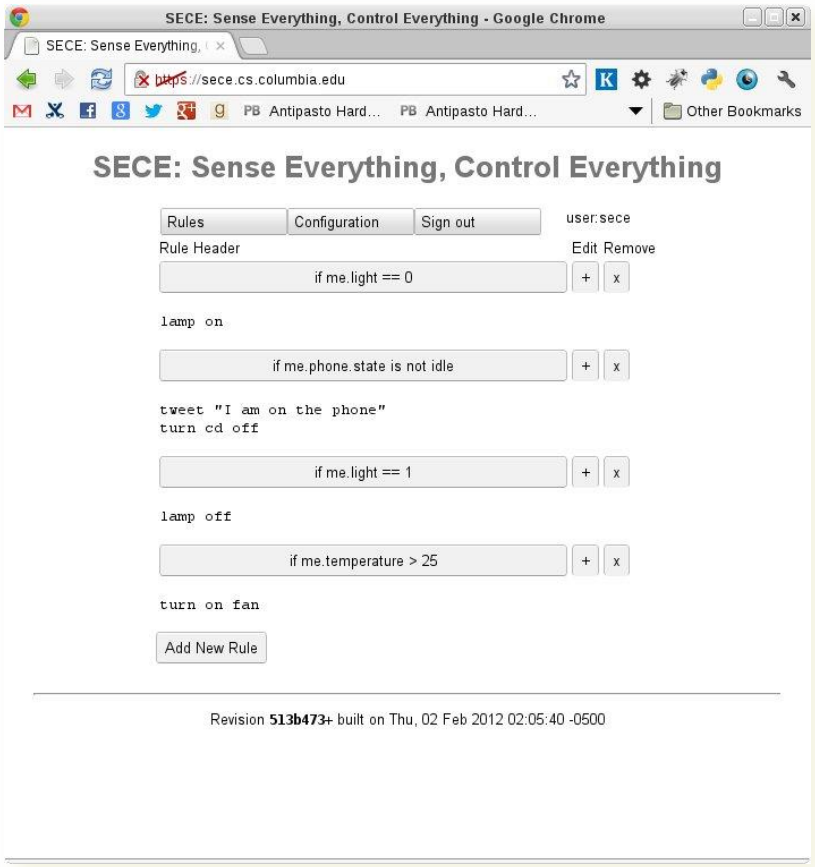
EnHANT project (Columbia U.)

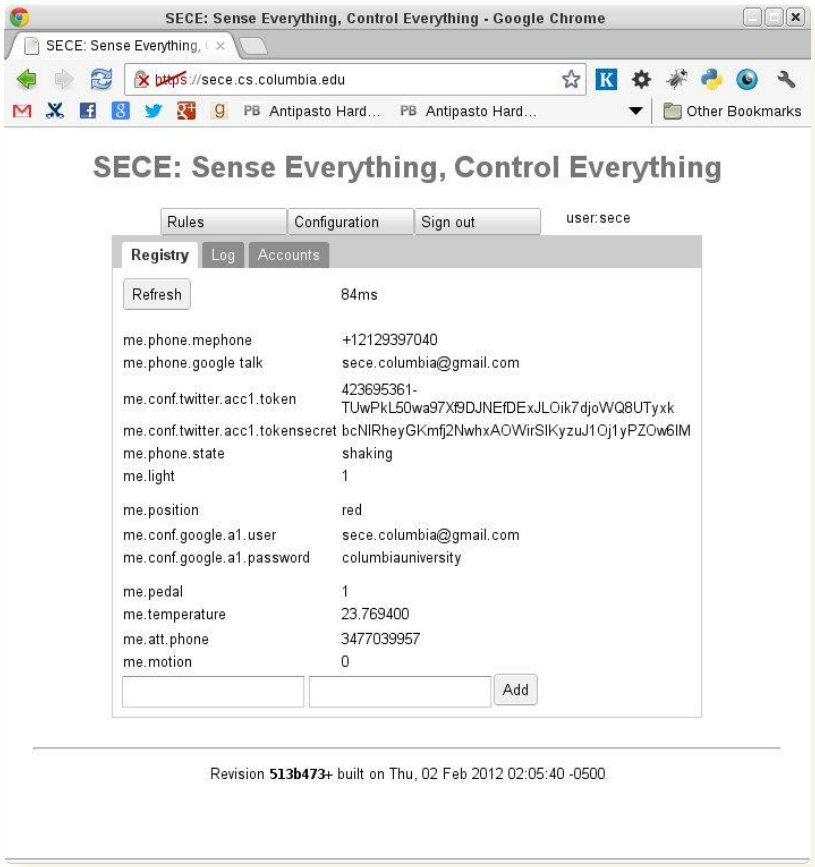
indoor lighting → 10 kb/s

Example: SECE (Sense Everything, Control Everything)

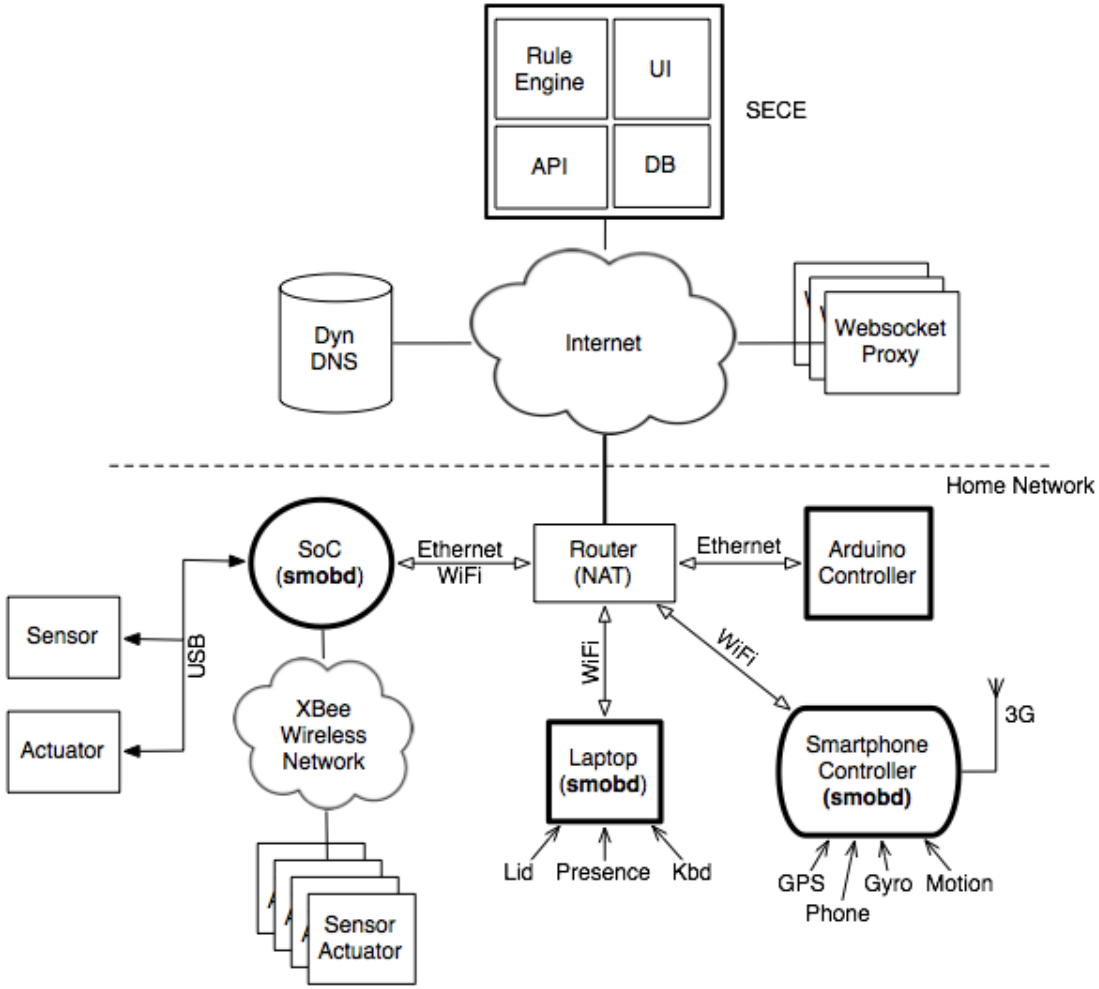
- Web-based user interface
- Rules in domain specific language
- Interface to online services
- Interface to communication devices
- **Sensor and actuator infrastructure**

SECE User Interface





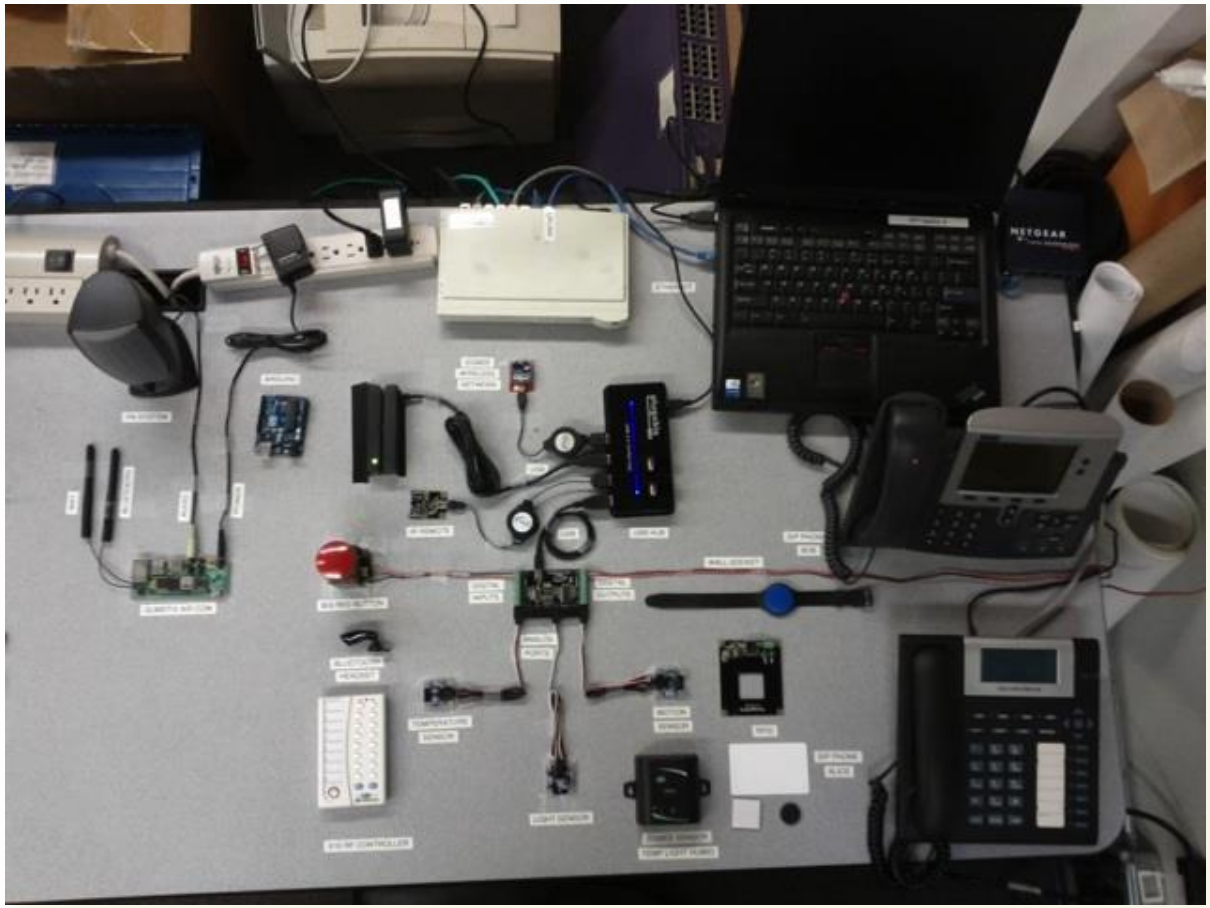
Infrastructure for Sensors and Actuators



- Conventional Devices
- USB (Phidgets)
- Wireless (XBee)
- Tiny (Arduino)
- Communication
- VoIP phone
- Skype
- Legacy (X10)

Sensors and Actuators in IRT lab

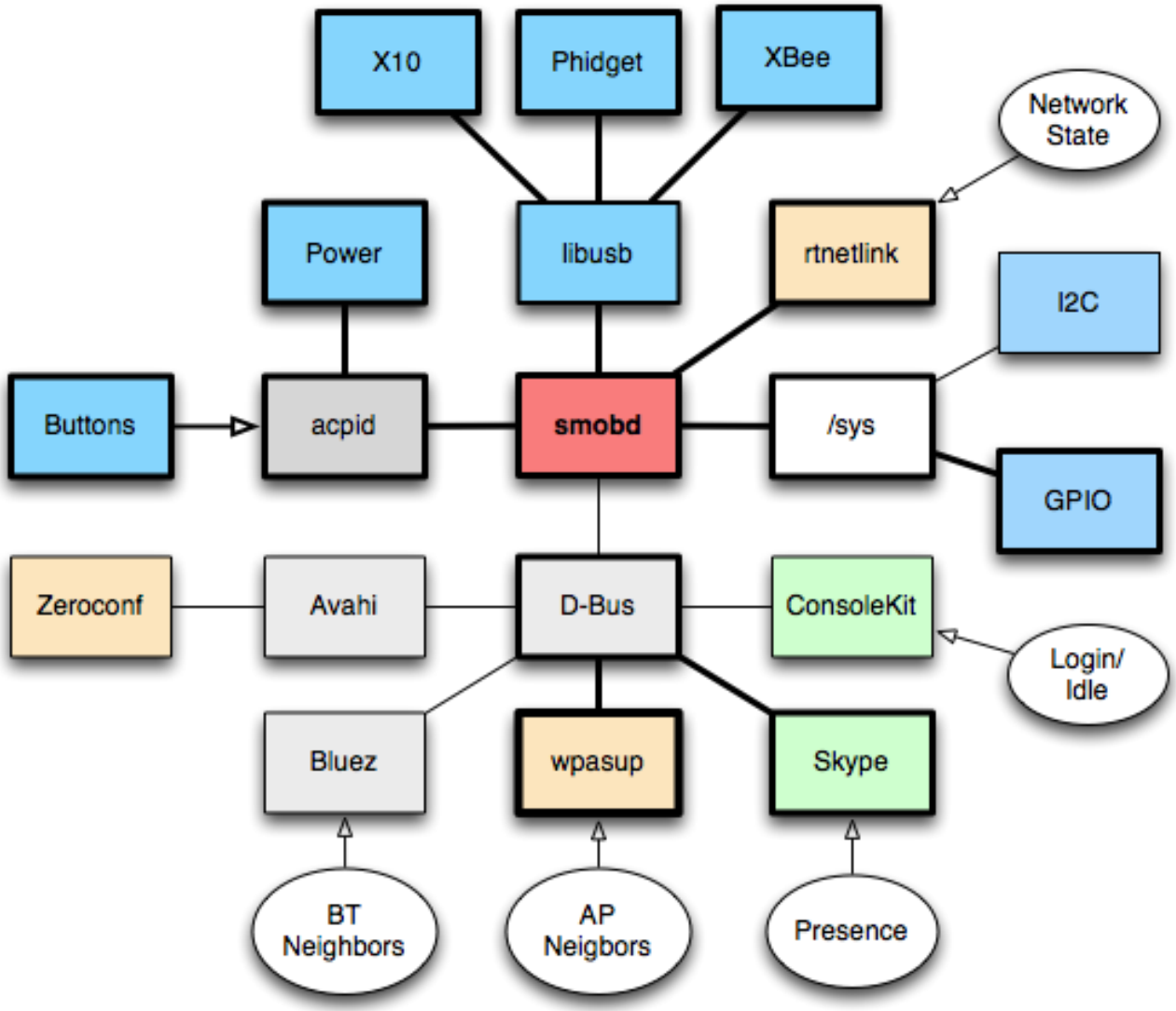
What it really looks like



Sensor and actuator testbed

XBee door lock

smobd: Subsystems & Interfaces on Linux



Conclusion

- M2M is not a single technology → technology enabler
- Build on secret of Internet: simple protocol building blocks that can be combined
  - accommodate wide
- Address key infrastructure challenges:
  - flexible network access
  - in-field upgrades
  - scalable security models