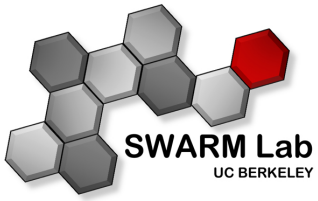
Smart Dust and Sensory Swarms

Kris Pister
Prof. EECS, UC Berkeley

Founder & Chief Technologist
Dust Networks, a Linear company



dust networks™

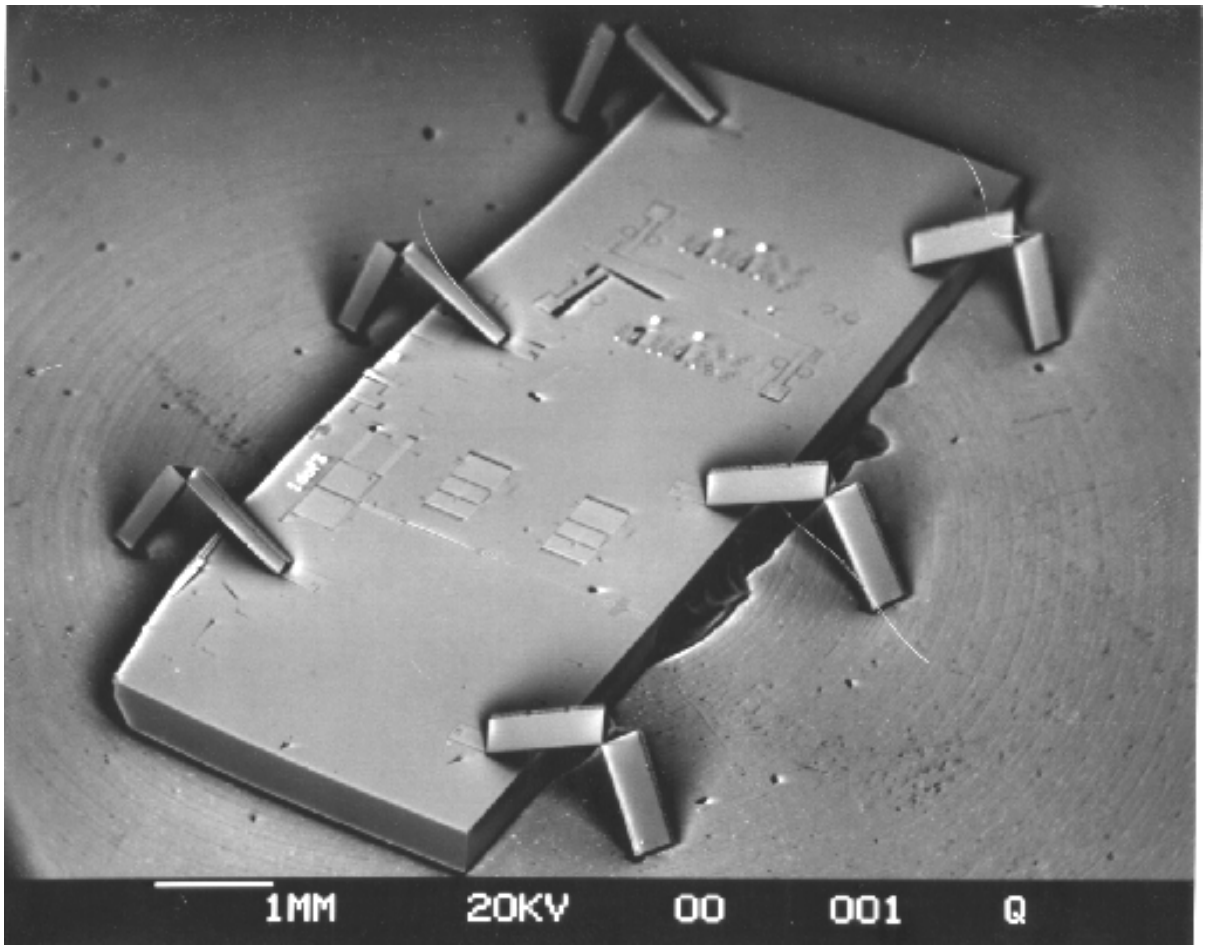
LINEAR TECHNOLOGY

The Swarm at The Edge of the Cloud

TRILLIONS OF CONNECTED DEVICES

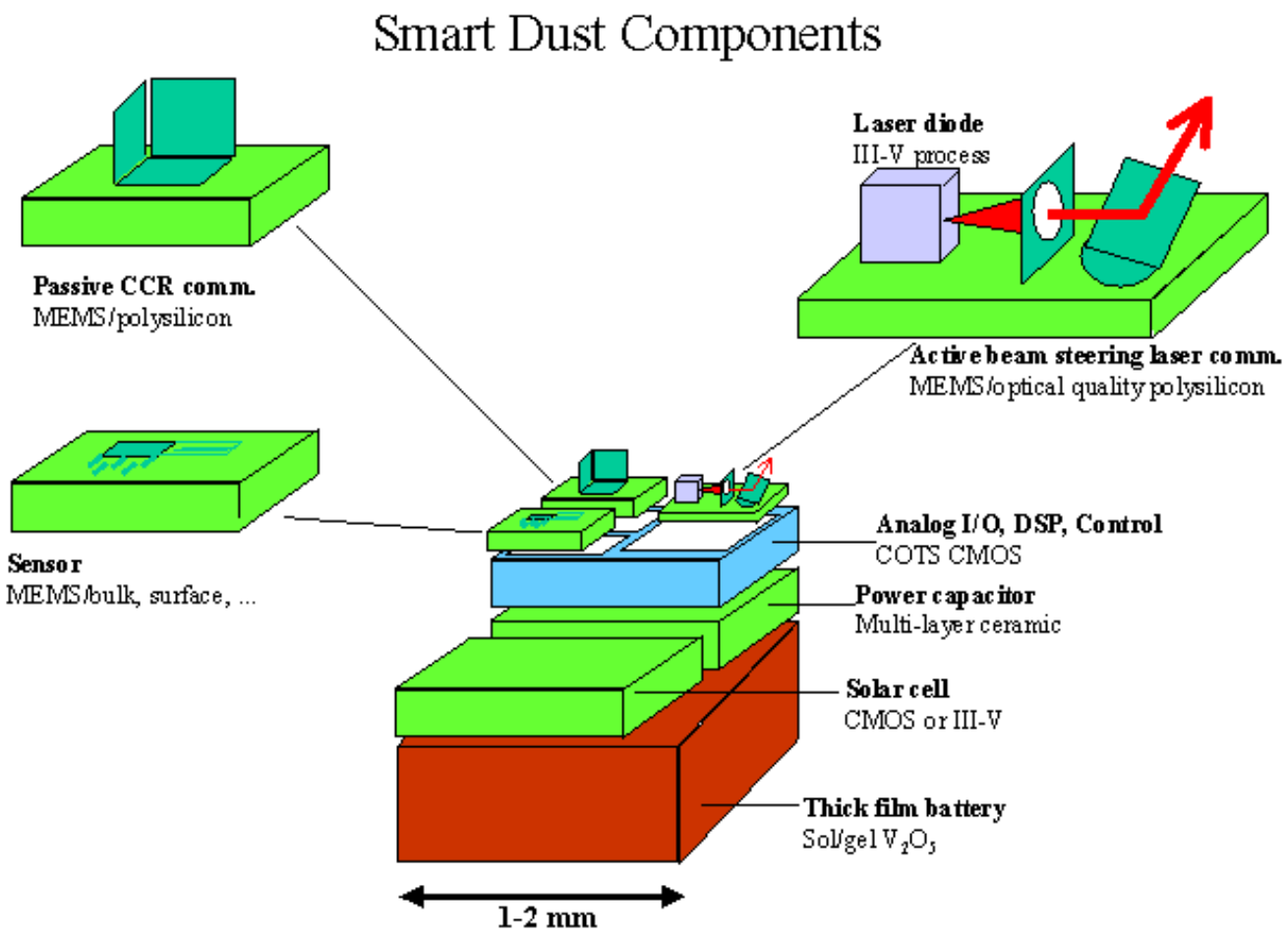
[J. Rabaey, ASPDAC'08]

Micro Robots, 1995



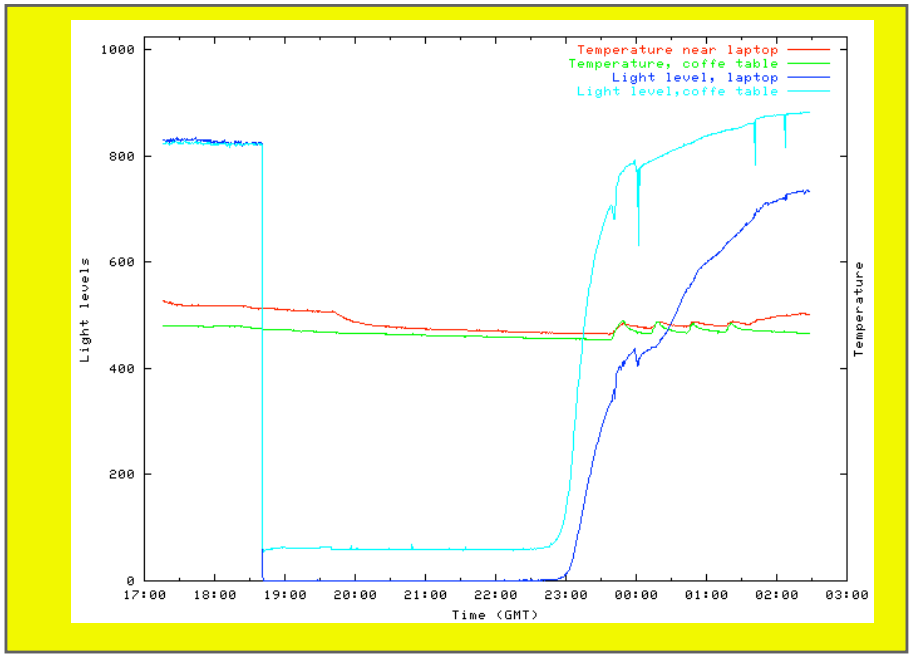
Goal: Make silicon chips that walk. (Richard Yeh)

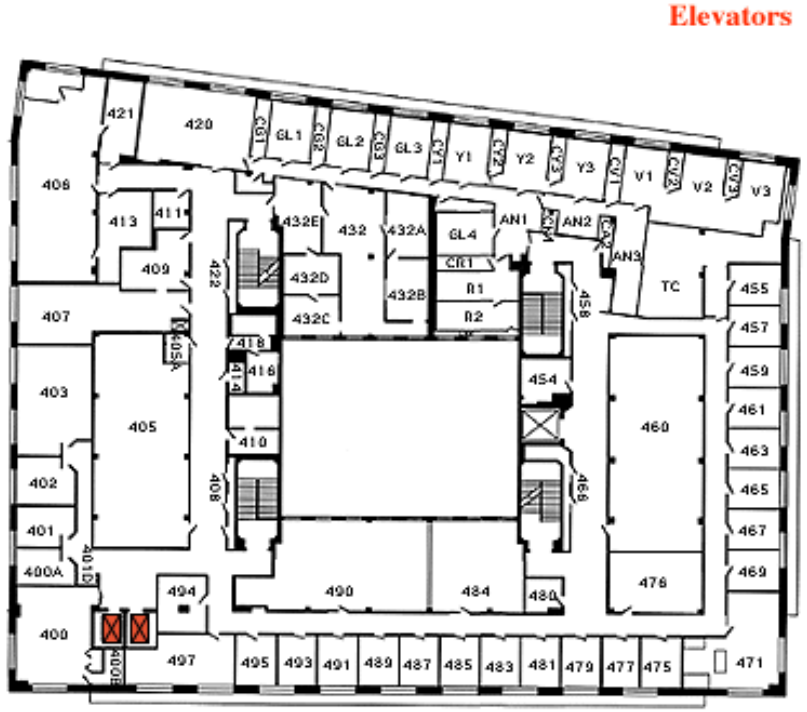
Smart Dust, 1997



Smart Dust, 2001

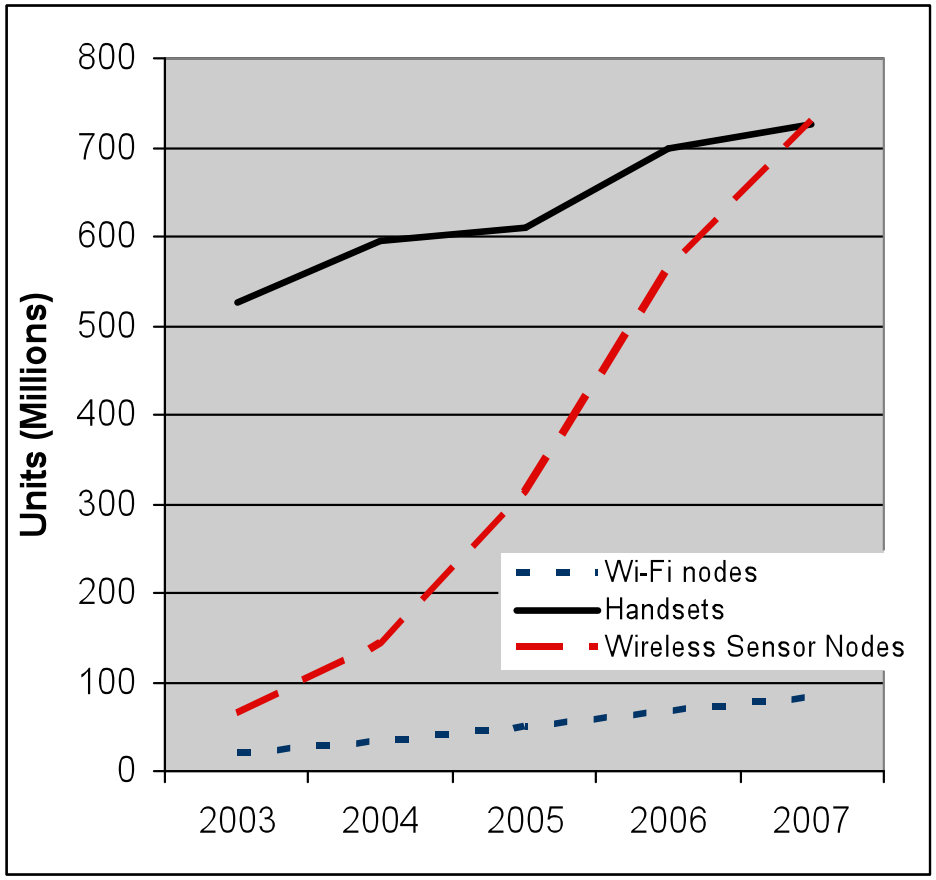
Building Energy System (ucb, 2001)





- 50 temperature sensors on 4th floor
- 5 electrical power monitors
- 1 relay controlling a Trane rooftop chiller

Sensor Networks Take Off!



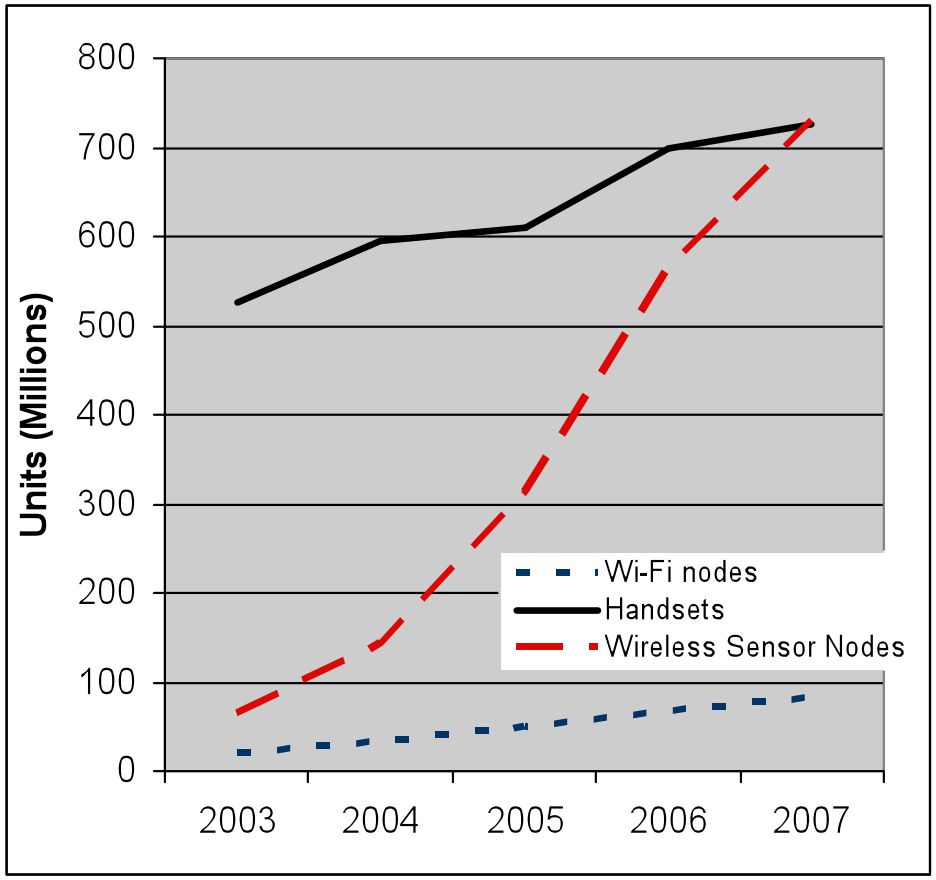
$8.1B market for Wireless Sensor Networks in 2007

Source: InStat/MDR 11/2003 (Wireless); Wireless Data Research Group 2003; InStat/MDR 7/2004 (Handsets)

Celebrity Endorsement

~~Sensor Networks Take Off!~~

Industry Analysts Take Off!



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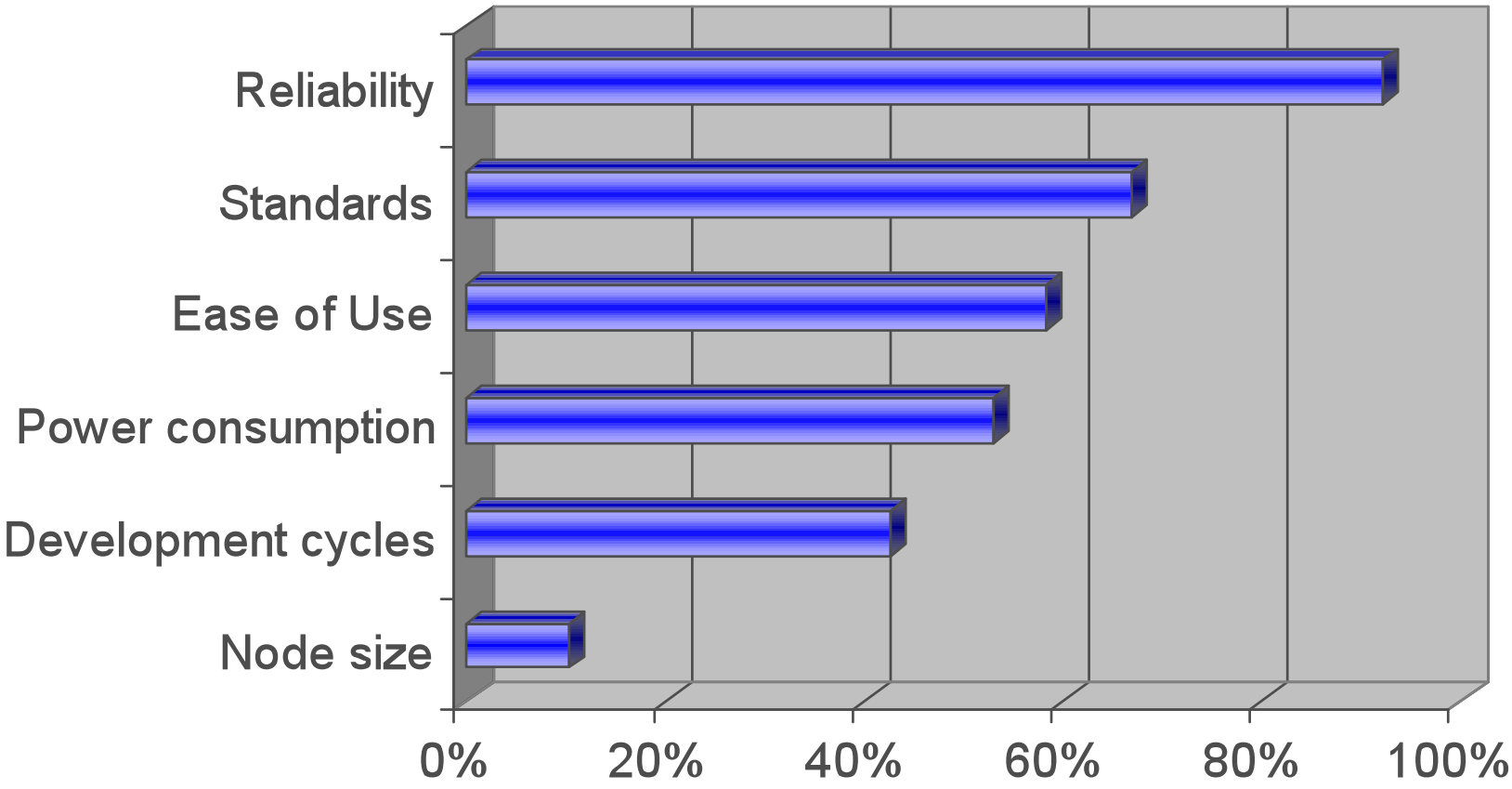
Barriers to Adoption

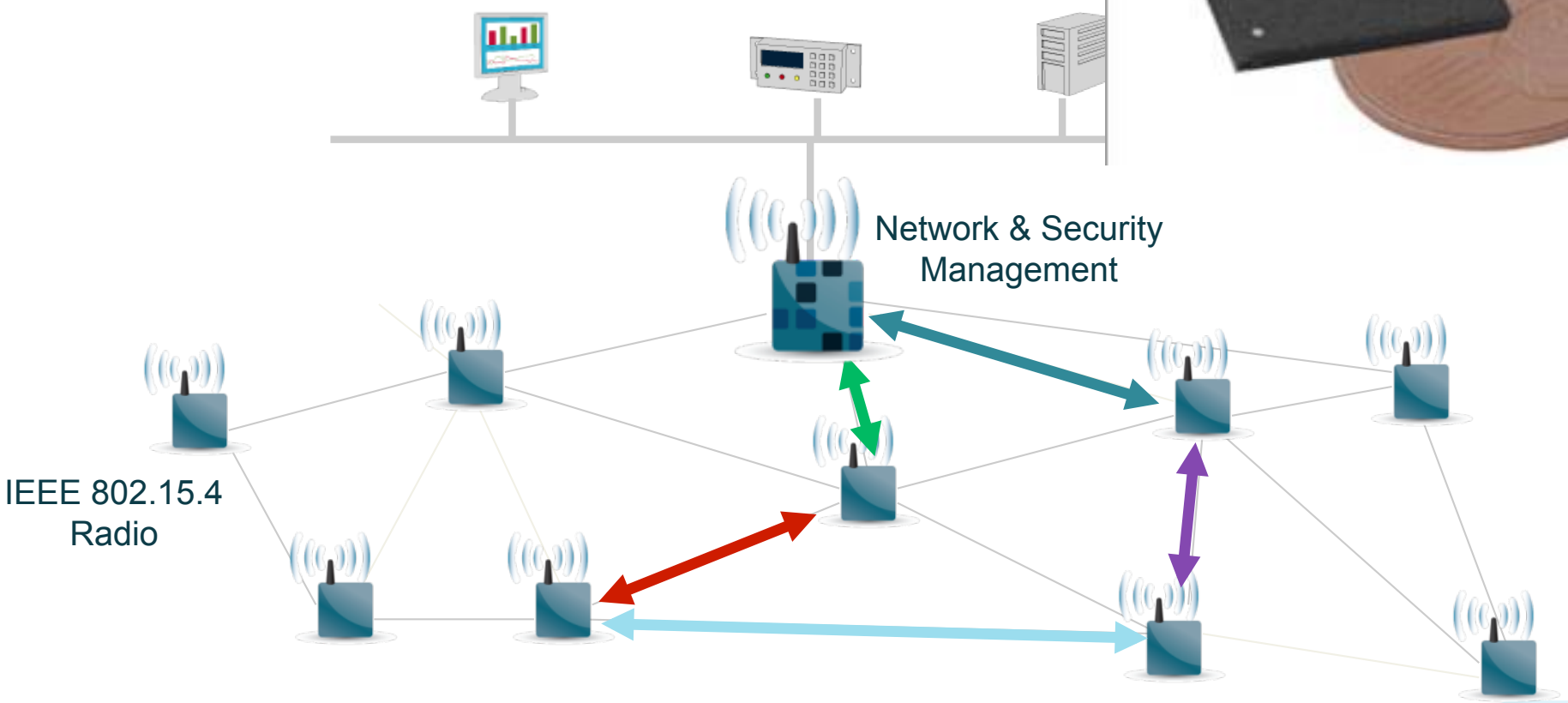


OnWorld, 2005

The Requirements

- Deploy devices ANYWHERE
- The data must be RELIABLE
- No battery changes for ~ DECADE

Network Architecture



- Time slotted and synchronized for **low power** and **scalability**
- Full mesh and channel hopping for wire-like **reliability (>99.99%)**
- Every node can run on **batteries** (or energy harvester) **for 10+ years**

- Incorporated into WirelessHART (IEC62591), ISA100.11a, WIA-PA, and IEEE 802.15.4E **standards**

Wireless HART Architecture (from ABB)

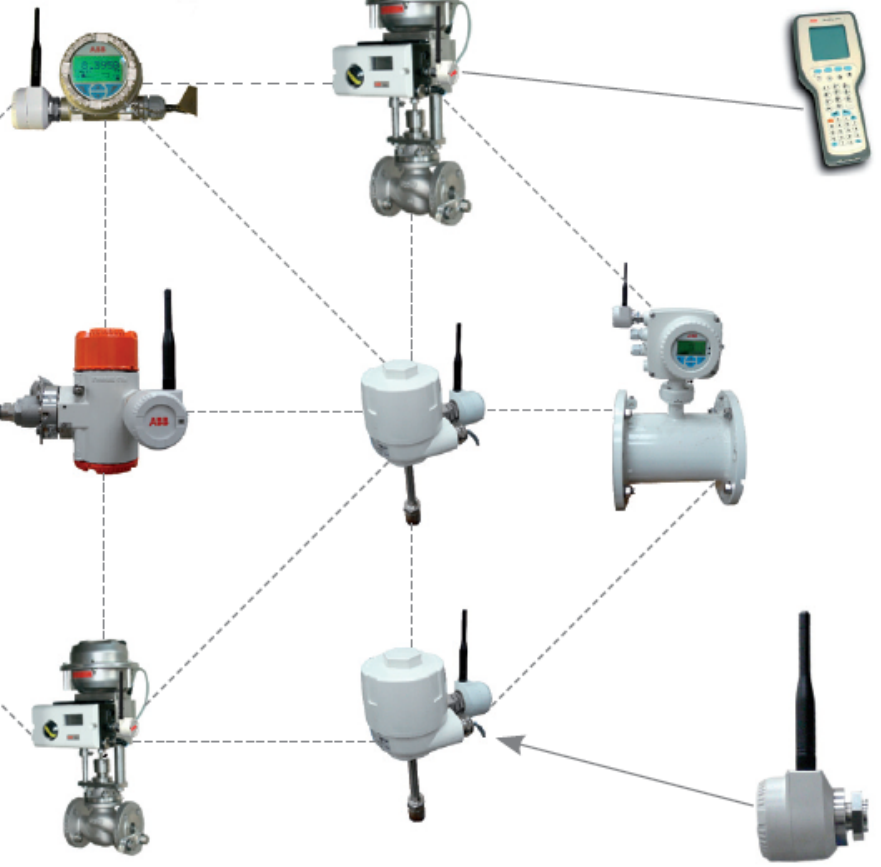
Asset Management application

System 800xA

High speed bus
(Modbus - Fieldbus - Ethernet)

WirelessHART Gateway

WirelessHART mesh network



Emerson offerings, 2007 (Dave Farr presentation)

We Offer The Widest Portfolio Of Wireless Products In The Industry

Shipping Now

Shipping in 2008

Pressure

Temperature

Level

Flow

Vibration

Density / Viscosity

Multi-point Temperature

Gas Specific Gravity

Gas & Liquid Analysis

Oil & Gas Remote Control

Device 'Stranded Diagnostics'

Field Device Communicator

Discrete

Radar Level

Wireless Gateway

Level Switch

Valve Positioners

Asset Management Software

Middle East Desert Sand Storms

Emerson Process Managmenet, *Extreme Wireless Applications*

Emerson Process Managmenet, *Extreme Wireless Applications*

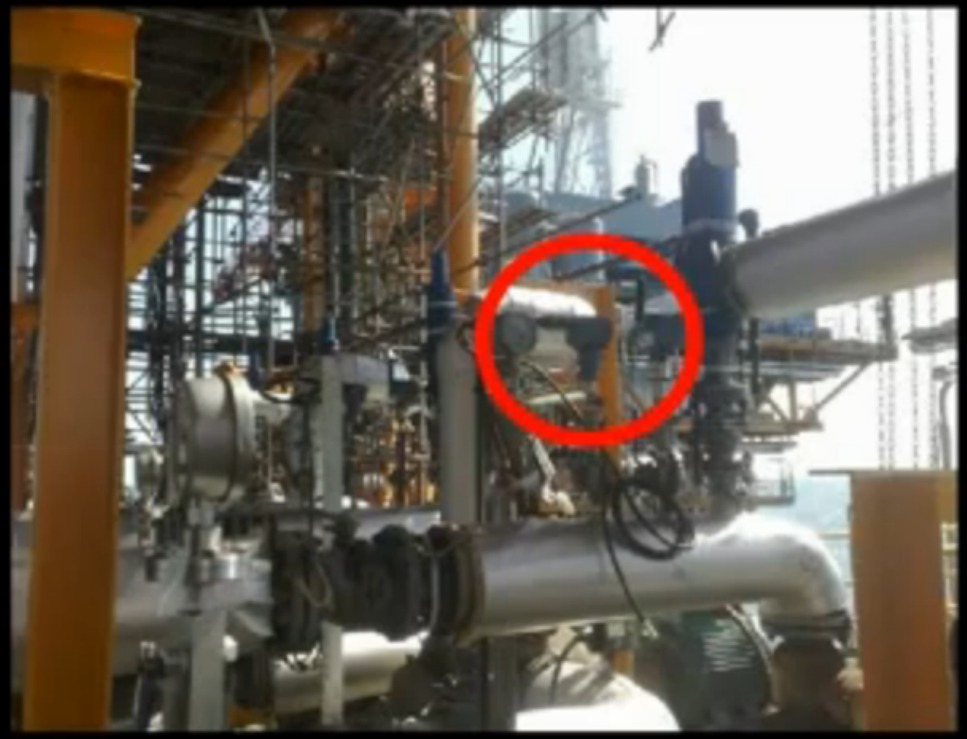
Rotating filter with DP transmitter going down in the steel tank and is sometimes immersed.

Emerson Process Managmenet, *Extreme Wireless Applications*

In Alaska, measures leak detection of pipeline running under a road mile from nearest device/gateway.

Emerson Process Managmenet, *Extreme Wireless Applications*

FPSO – Floating Platform, Storage and Offloading



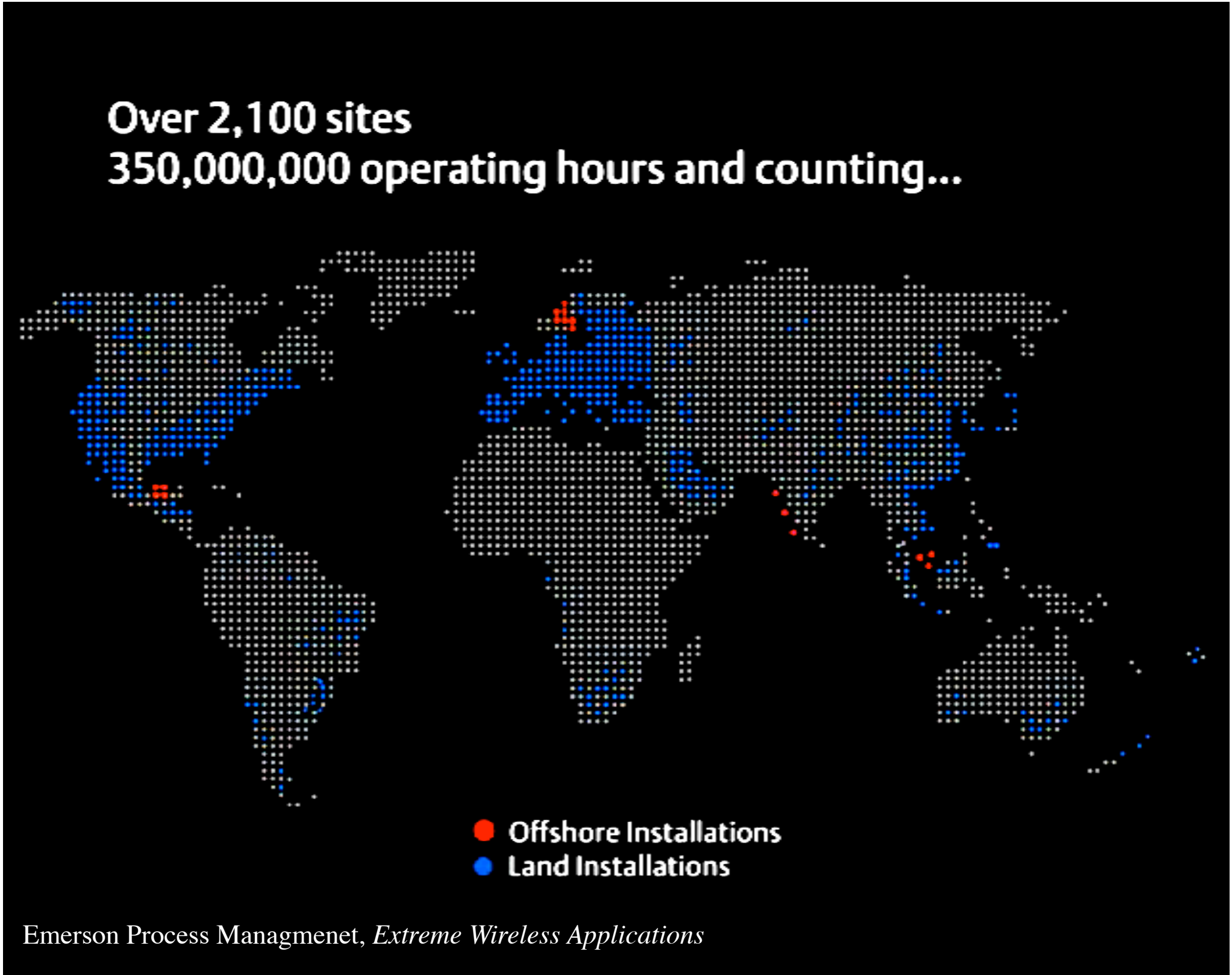
Emerson Process Managmenet, *Extreme Wireless Applications*

Mobile – transmitters on a truck, drive up to a network for temporary mobile monitoring.

Emerson Process Managmenet, *Extreme Wireless Applications*

Aluminium plant (100 Gauss) magnetic field - nail sticking directly vertical on the transmitter being held up by the magnetic field.

Emerson Process Managmenet, *Extreme Wireless Applications*

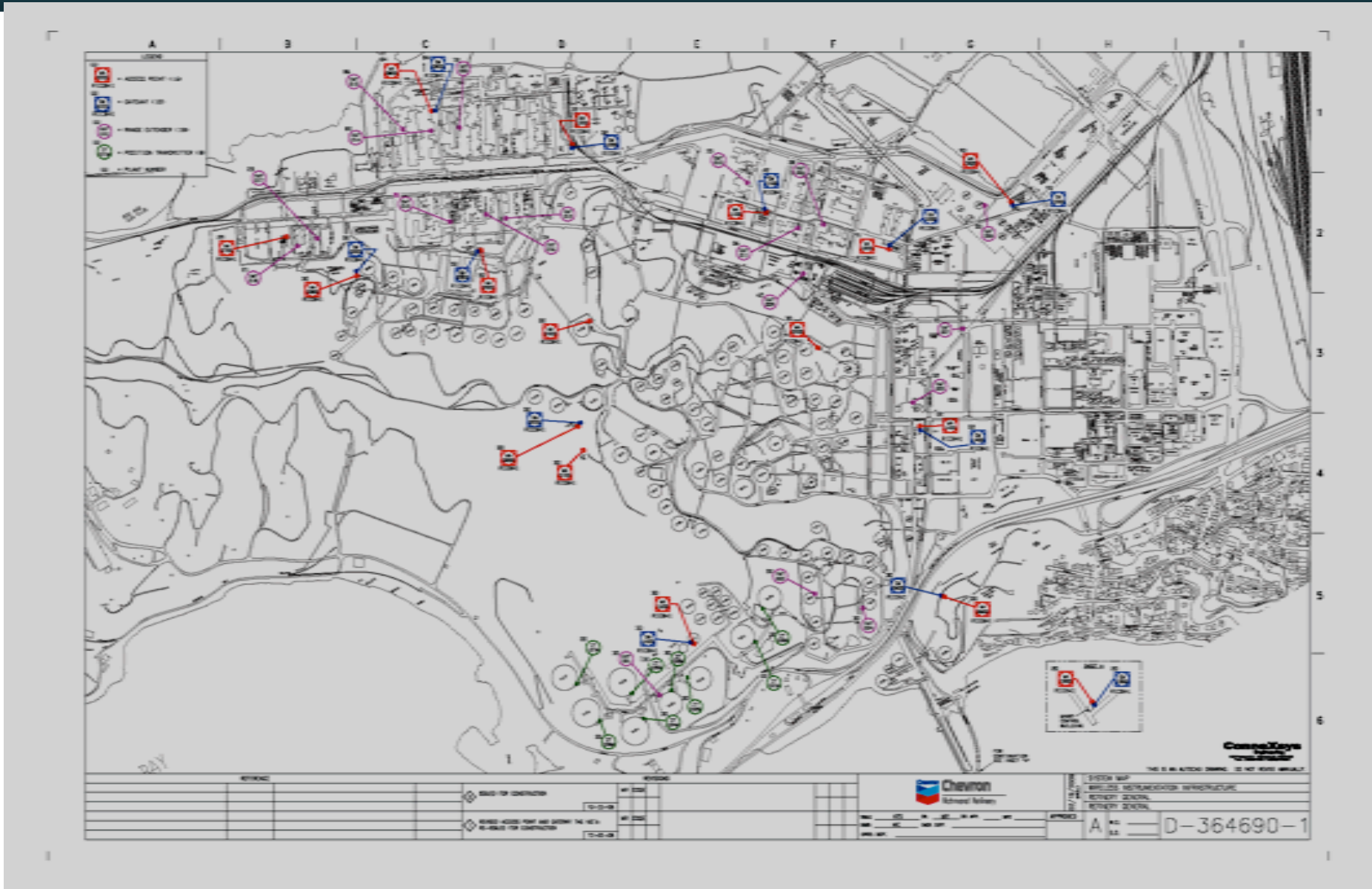


Emerson Process Managmenet, *Extreme Wireless Applications*

Chevron's Richmond Refinery

1 km

Richmond Refinery Wireless Umbrella



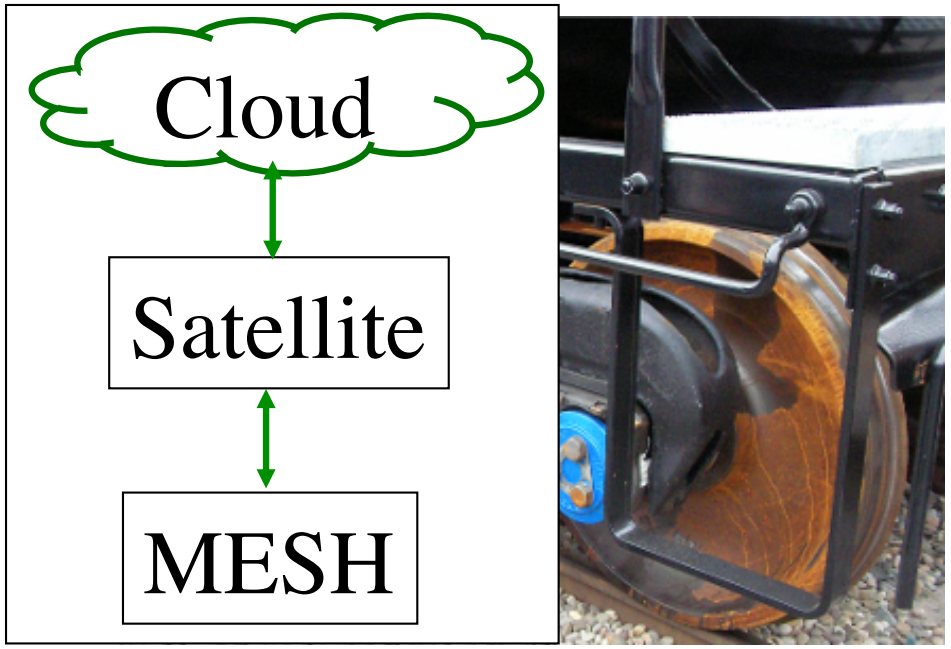
3 km^2, 90% coverage

24

Wheeling-Pittsburgh Steel

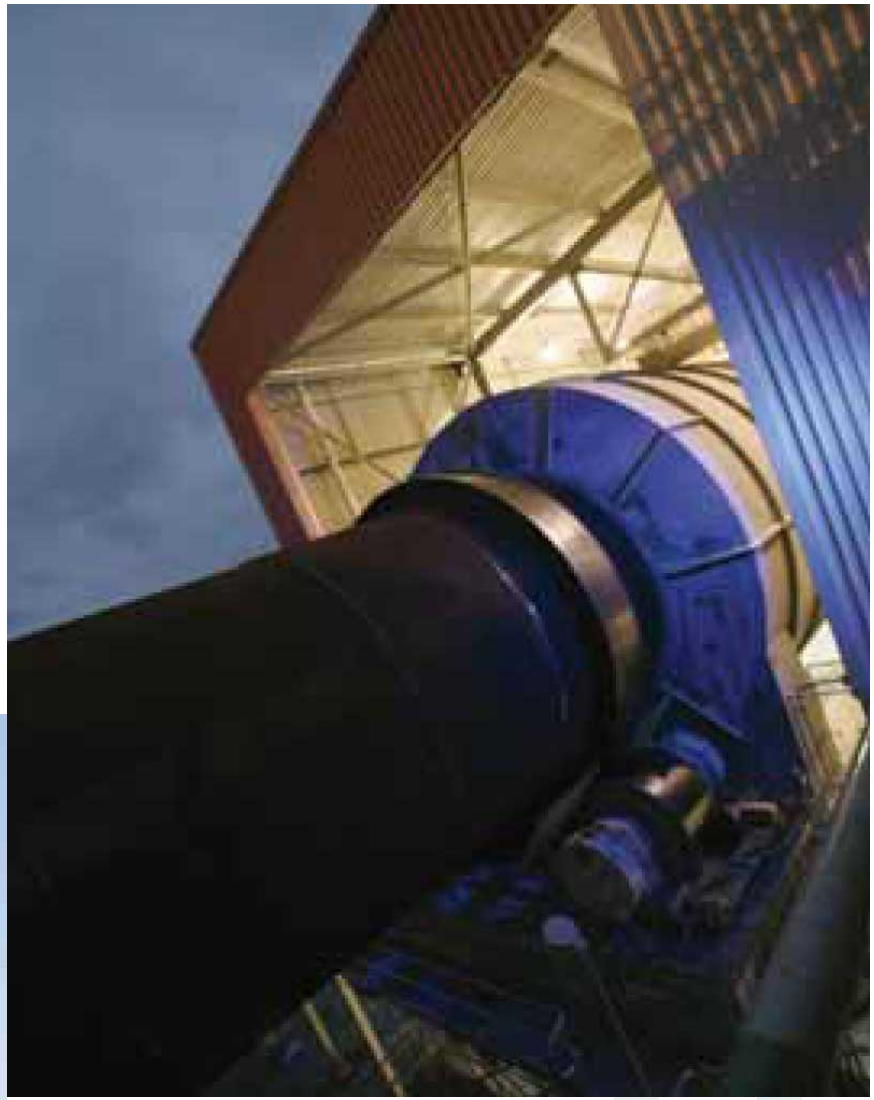
Smart Rail: Amsted Rail

- **Multiple sensors per car: bearing temp, hatches, …**
- **Installer toolset:**
  - **“A sledgehammer and a blowtorch”**



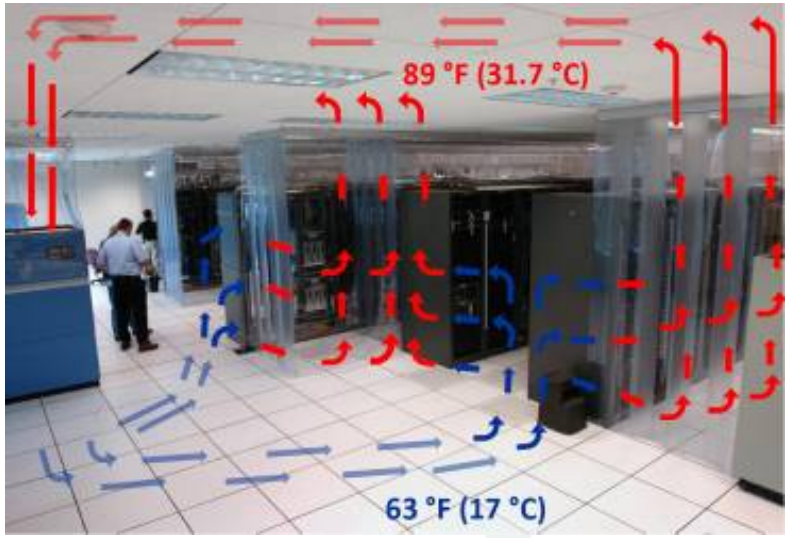
Lime Kiln at Pulp & Paper Mill

- Rotating lime kiln
- Need to monitor temperature
- 5% throughput improvement (reduced process time)



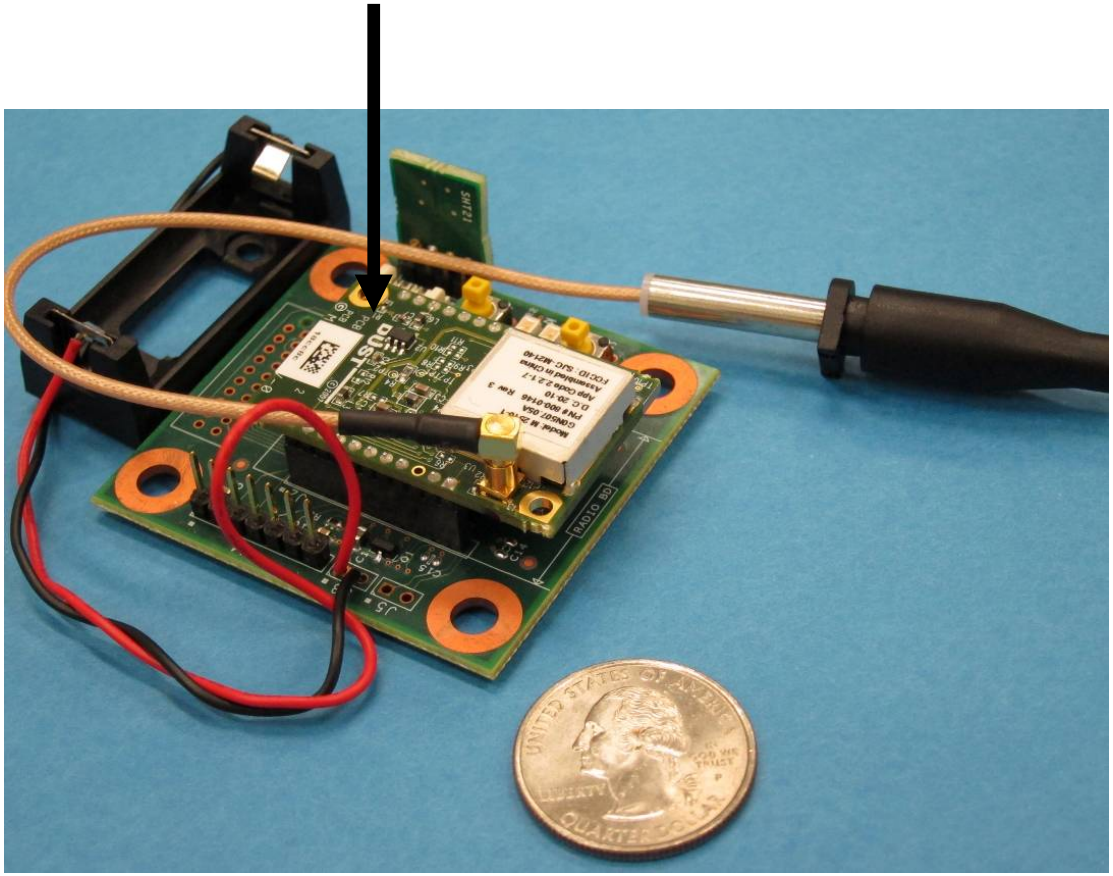
Data Center: Reduced operating costs

- Vigilent provides data center energy management service by deploying hundreds of sensors and control points in the data center
- No wires, no interruption to data center operations
- E.g. Verizon is saving > 55M kWh annually in 24 major data centers, reducing greenhouse gases by 66M pounds/year



Building Monitoring: IBM and The Met

- Hundreds of sensors monitor temperature and humidity to help preserve medieval art
- Historic building: requires no wires, no construction
- Builds a 3D "climate map" for predictive analytics & trending



Smart City: Parking, Streetline Networks

STREETLINE

Smart City: Parking, Streetline Networks

STREETLINE

Finding Parking

Variable Message Sign

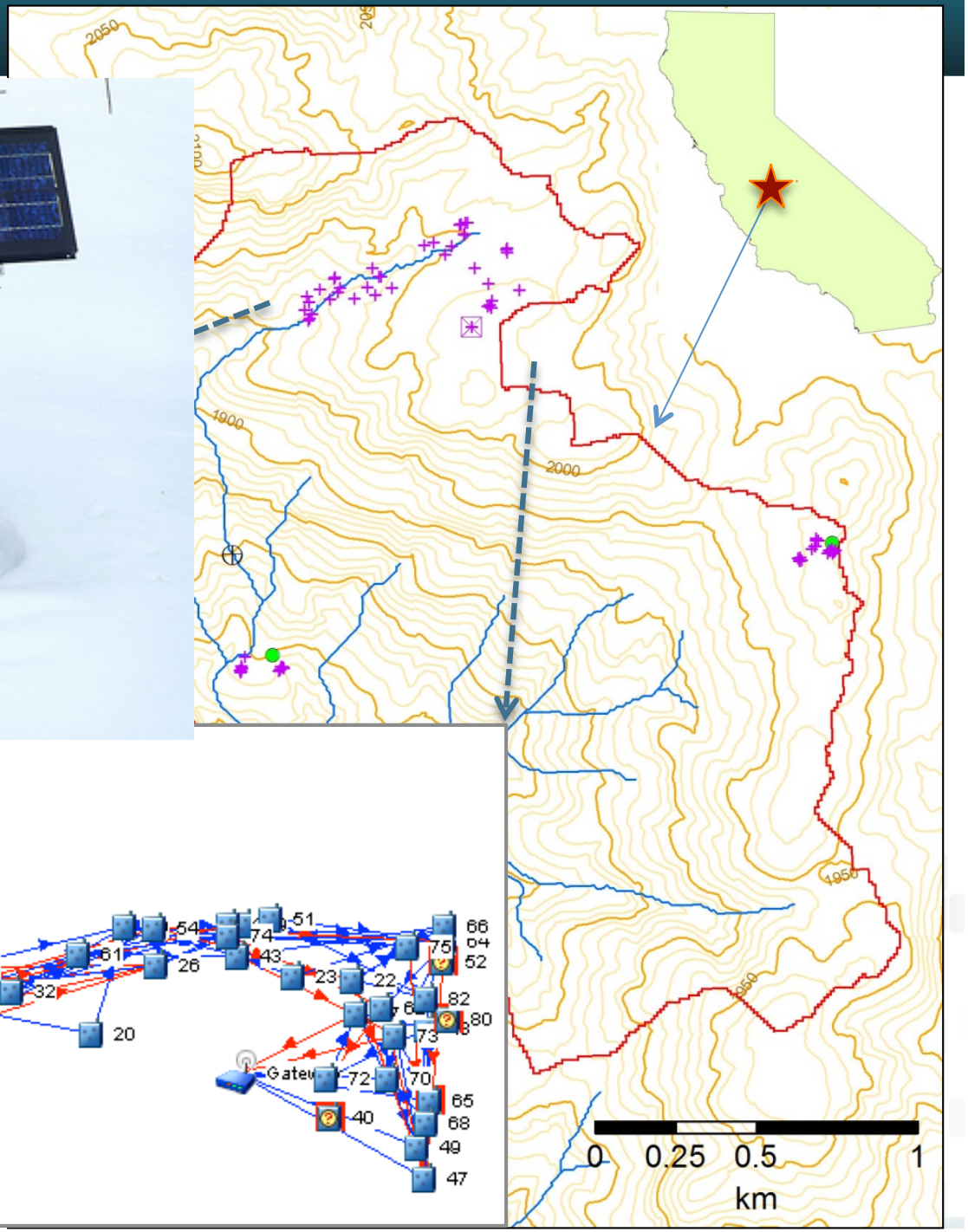
- **5 minute install**
- 2 to 3 year battery life
- Reflective display
- Networked

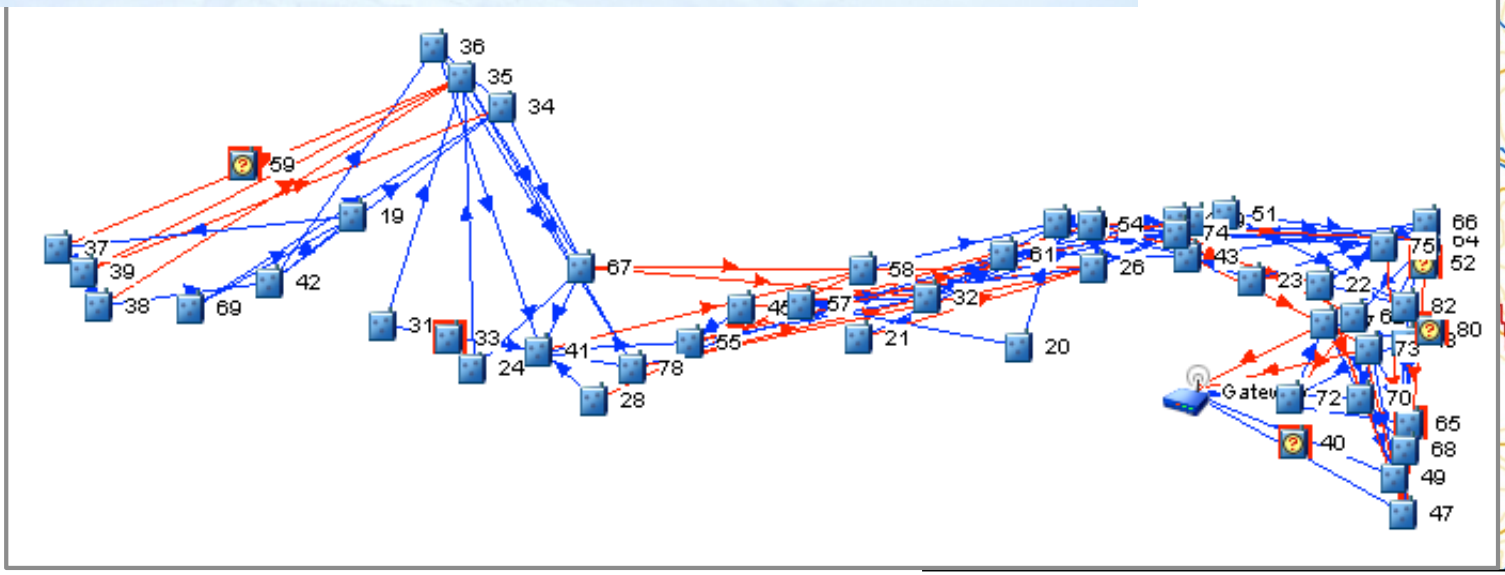
STREETLINE

Parker app

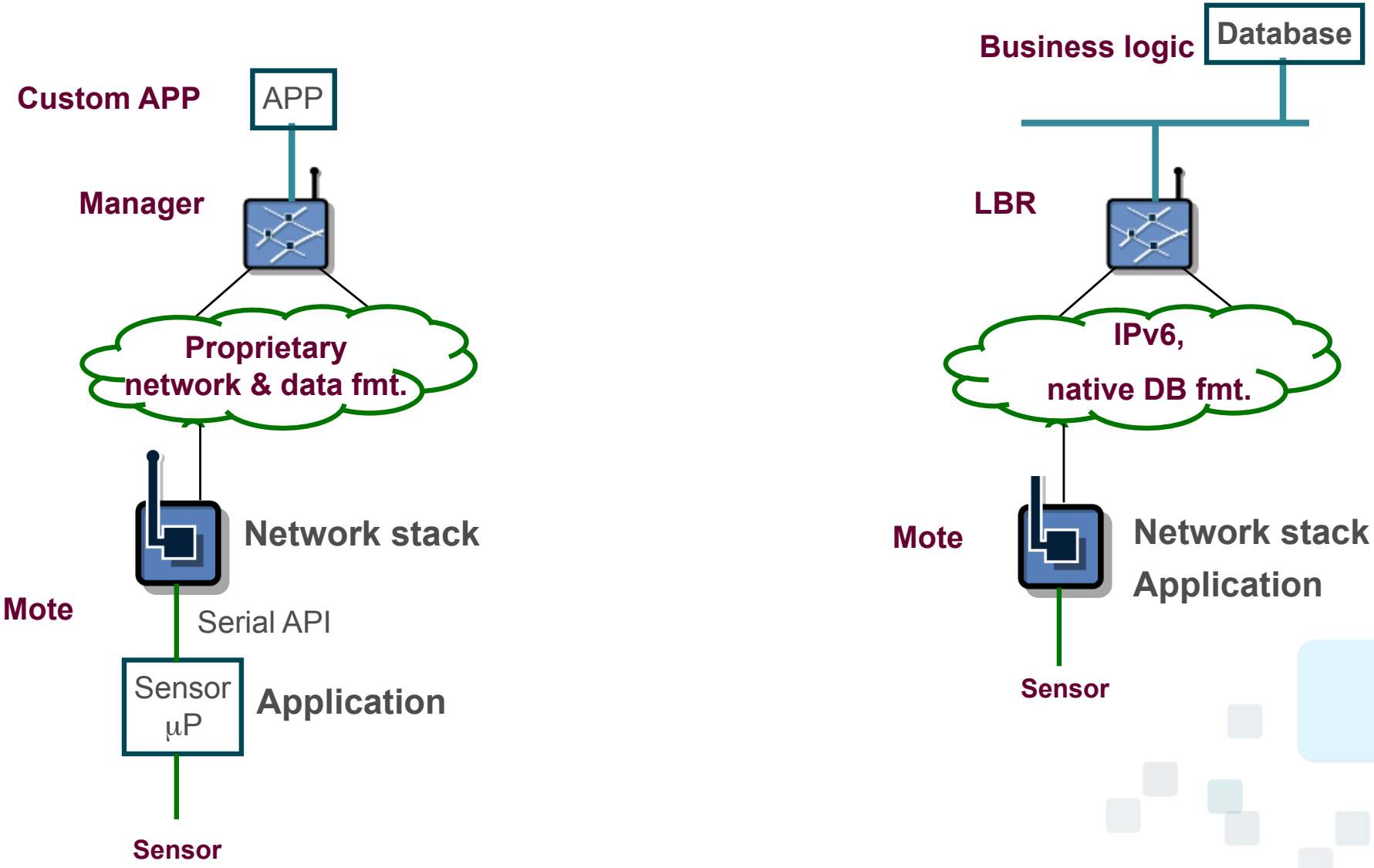
STREETLINE

Hydrology: Berkeley





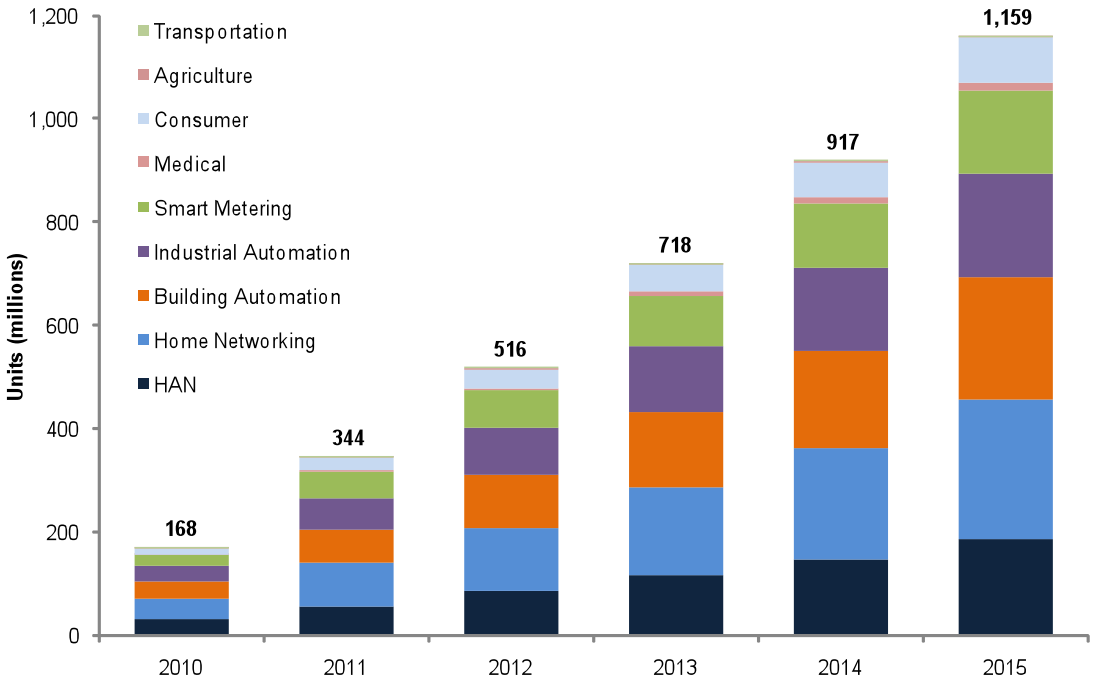
Evolving information flow in WSN



IEEE 802.15.4 Markets and Standards

Market Predictions

- **IEEE 802.15.4 and ZigBee WSN chipsets are expected to top 1.1 billion units in 2015, up from 168 million units in 2010**
- **WSNs dramatically cut deployment, operating and maintenance costs versus wires**



WSN Chipset Forecast (Mu)

Transportation: Parking garage monitoring and control, truck asset management
Agriculture: Soil temperature/moisture monitoring, livestock management
Consumer: Child locator tag, toys, other consumer products
Medical: Glucose meter, blood pressure monitor, other non-critical health, wellness, and fitness applications
Smart Metering: Electricity, gas, or water meters
Industrial Automation: Process monitoring, process control, machine health, perimeter monitoring/security
Building Automation: Lighting control, HVAC control, building security, door locks, and wet bar control (in hotels)
Home Networking: Media control products, including remote controls
HAN: Lighting control, thermostats, HVAC control, in home displays, appliance control and monitoring

Note: Forecasted data includes technologies IEEE 802.15.4 and ZigBee
Source: Wireless Sensor Network Technology Trends Report, Nov. 2010, West Technology Research Solutions

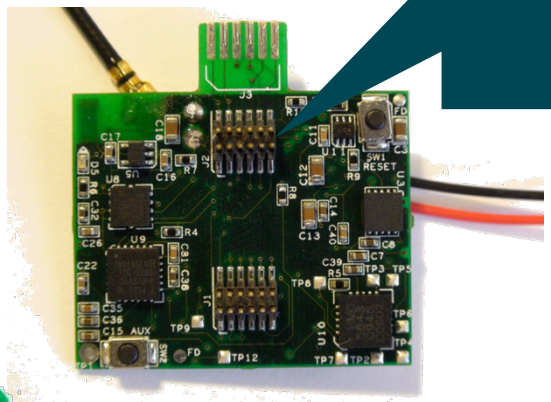
openWSN.berkeley.edu

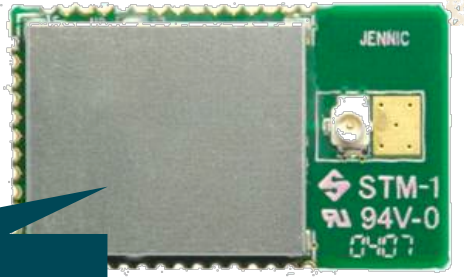
Dust Networks
Huron (Dust Oski)
uC/OS-II

- OpenWSN
- SmartMeshIP

UCB,
GINA (MSP,Atmel '231)
OpenOS

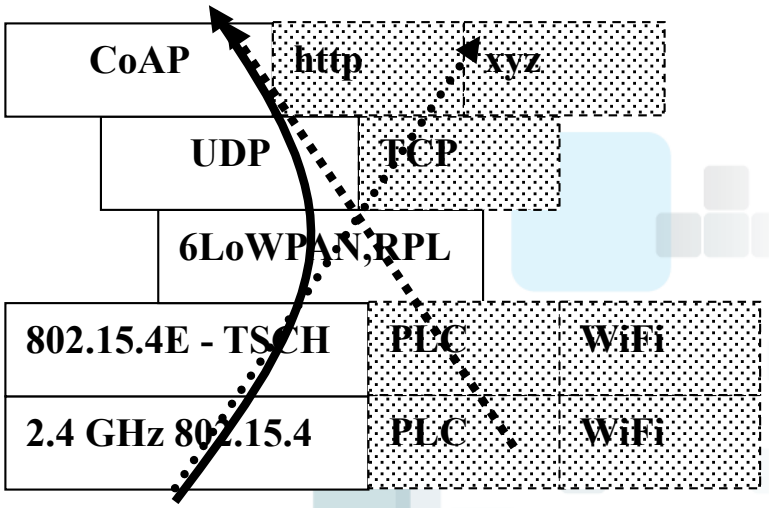
- OpenWSN





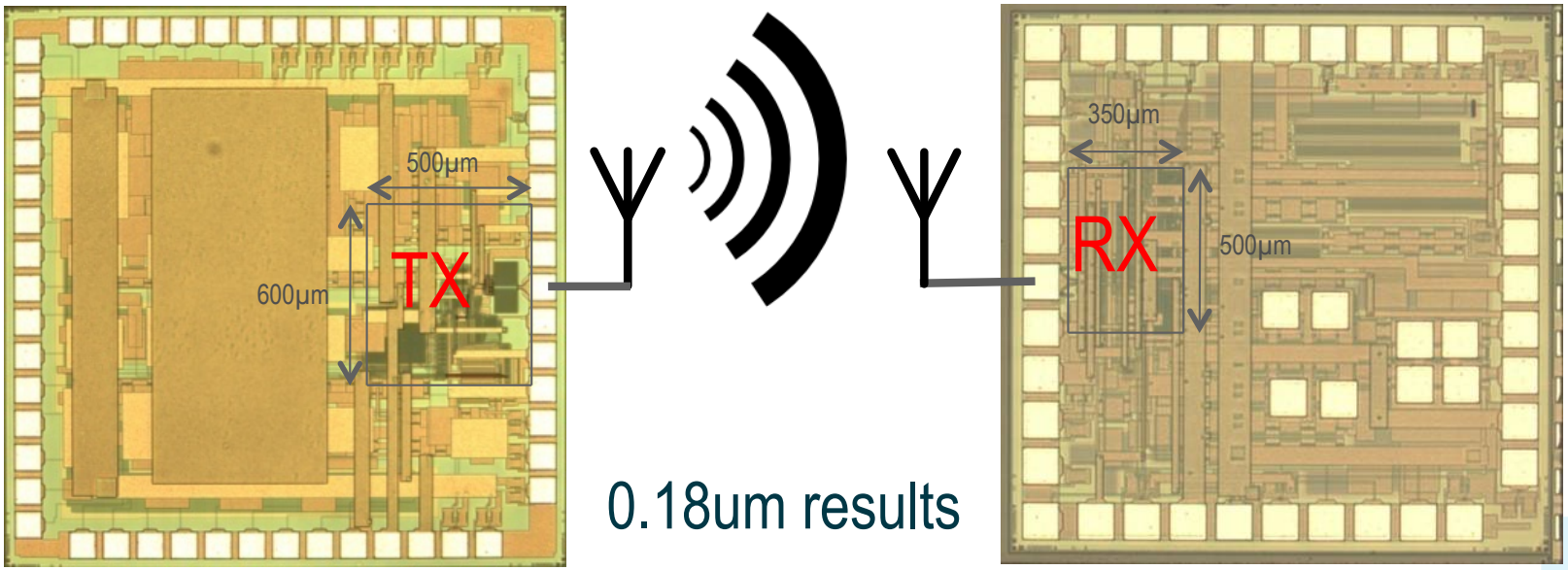
LBNL
Jennic JN5148
FreeRTOS

- "home brew"



0.1mm^2 Transceiver

- Mostly synthesized from standard cells
- Uses existing crystal for digital



0.18um results

Active area: 0.3 mm^2

Active area: 0.18 mm^2

- 10kbps 73dB link margin → meters of indoor communication range
- 0.1mm^2 in 65nm