ONRAMP WIRELESS

Connecting Anything with M2M Wireless Communications

Ted Myers

Co-founder and Chief Technology Officer

On-Ramp Wireless
Connecting the Internet of Things

On-Ramp Wireless Company Overview

Company

Founded: 2008

Employees: 85

Technology: RPMA™ based wireless networking platform for long range, wide-area, secure and low power M2M communications

Patents: 38 patents (15 granted); sole patent holder for RPMA™ Air Interface

Ecosystem

Awards

WORLD ECONOMIC FORUM Technology Pioneer 2011

GTM RESEARCH TOP10 Vendors to Watch

cleantech GROUP LLC

Fierce WINNER 15 FierceBiotech

GTM TOP10 VENDORS TO WATCH

Greenbang Efficiency Awards category winner 2011

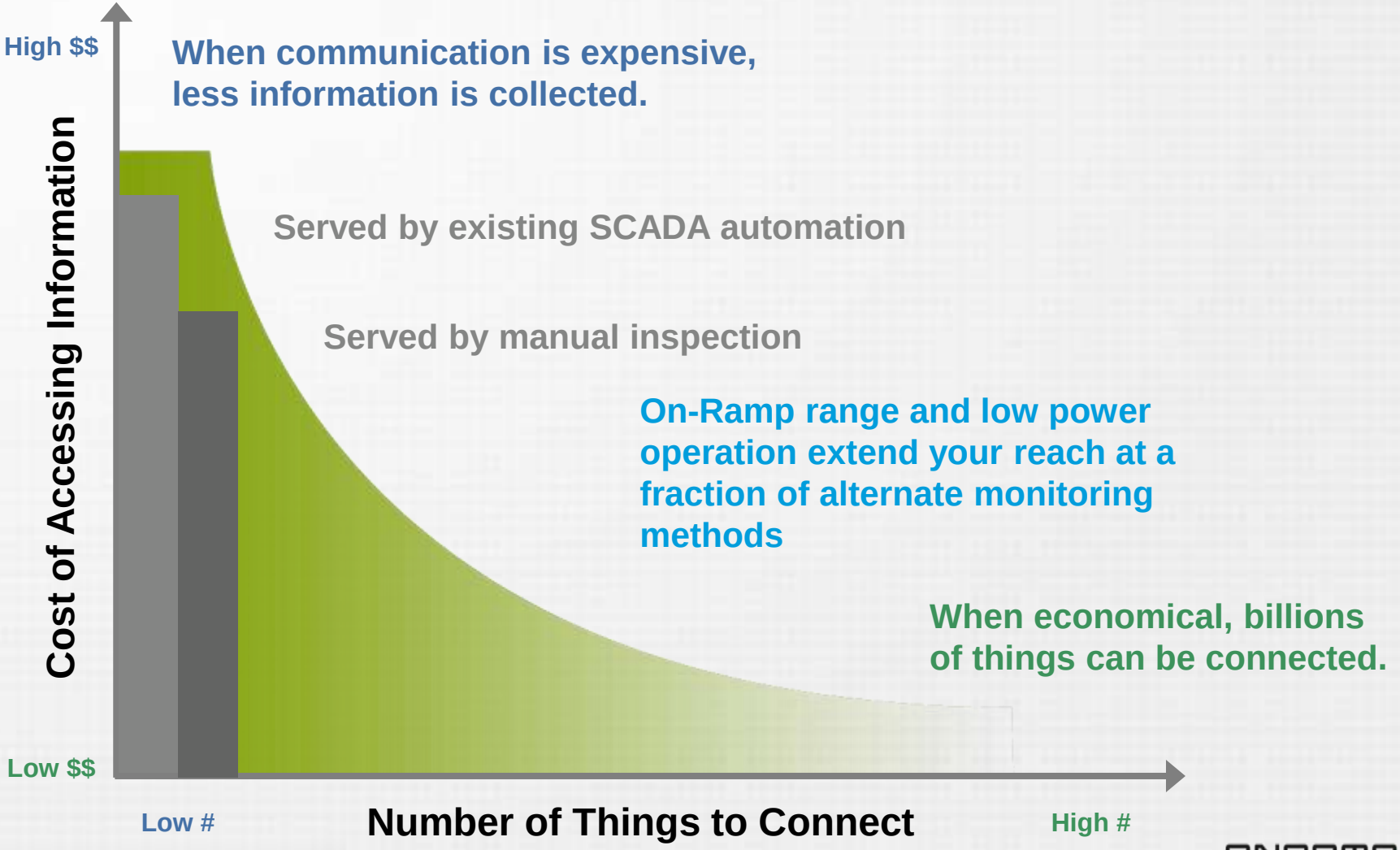
ONRAMP WIRELESS

Lack of the Right Wireless Solution *Prevents Industry From Saving Billions*

Unconnected Assets	Why Are They Not Covered?	Value of Actionable Data
Utility Distributed Sensing & Metering 	**Coverage** **Cost** **Capacity**	• $100B per year societal impact of power losses - EPRI • 30 minute reduction in outage time for San Diego $5M/year in benefit
Below Ground Distribution 	**Reliability** **Power**	• San Diego below ground fault detection estimated at $24M/year • Early identification of pipeline leaks avert catastrophic failure - one incident @ PG&E $1.4B
Oil & Gas Exploration & Distribution 	**Network Management**	• Cost of manual pipeline inspection and remediation $100K/mile • Manual inspection of pipelines can cost as much as $1,000/sensor/year

Connecting Things that are Unconnected

Maximize Intelligence via Wide Area Automation



Wireless Technologies for M2M

	RPMA™	Cellular	900 MHz ISM	Zigbee/ISA100
Vendors	**On-Ramp Wireless**	**AT&T, Verizon**	**Honeywell, Freewave, vMonitor,**	**Emerson, Honeywell GE, etc.**
Carrier Grade	**Yes**	Yes	No	No
Receiver Sensitivity	**-142 dBm**	-112 dBm	-109 dBm	-105 dBm
Coverage	**Wide area, hard to reach areas, rural, below ground, 25x advantage**	Regional, spotty in remote regions	Use mesh and repeaters to extend coverage. Point solutions.	Plant, wellhead level, short range with mesh
Capacity	**High; thousands of endpoints per AP**	High endpoint throughput/capacity	Low; few endpoints per AP	Low; few endpoints per AP
Battery Powered Device Support	**Yes**	No	No	No
CapEx/ Sq. mile	**Low: above ground and below ground**	Low if coverage available; very high to expand	High	High
OpEx	**Low**	High	High	High
Wide Area	**Yes**	Yes	Yes	No
Below Ground	**Yes**	No	No	No

Random Phase Multi Access

[2.4 GHz Frequency] [1 MHz Occupied Bandwidth]

Physical Layer □ -142 dBm Receive Sensitivity
Air Interface □ Random Phase Multiple Access™

Coverage
- 30 dB link budget advantage over competing free spectrum radios
- 25× range advantage / 600× coverage
- 6-10 mi suburban range (>40 mi outdoor LOS)
- Below ground coverage for utility assets

Robustness
- Large link budget provides robustness to interference
- Demodulation of signals 32 dB below noise floor
- Simple capacity and redundancy enhancements with added infrastructure

Capacity
- Star topology has significant capacity advantage
- 25-100× higher capacity compared with competing systems
- No system capacity degradation with increase in range/deterioration in link condition

Security
- Hard to detect signals transmissions below noise floor
- Built in AES 128/256
- Additional security features supported above media access layer

Power Consumption
- Power consumption on par with or better than competing systems
- Power savings through ultra efficient air interface and protocol
- Up to 20 year battery life for some applications

System Cost
- Significantly fewer infrastructure points (up to 100× less) required due to extreme coverage
- 10× or better TCO compared with mesh systems
- Additional savings from low installation and maintenance cost

Technology Value Proposition Outline

The On-Ramp Wireless Technology Differentiation

- Coverage
- Capacity
- Power Consumption

The Table Stakes of a Secure, Reliable Wide Area Network

- Coexistence in the ISM Band
- Security

Random Phase Multi Access

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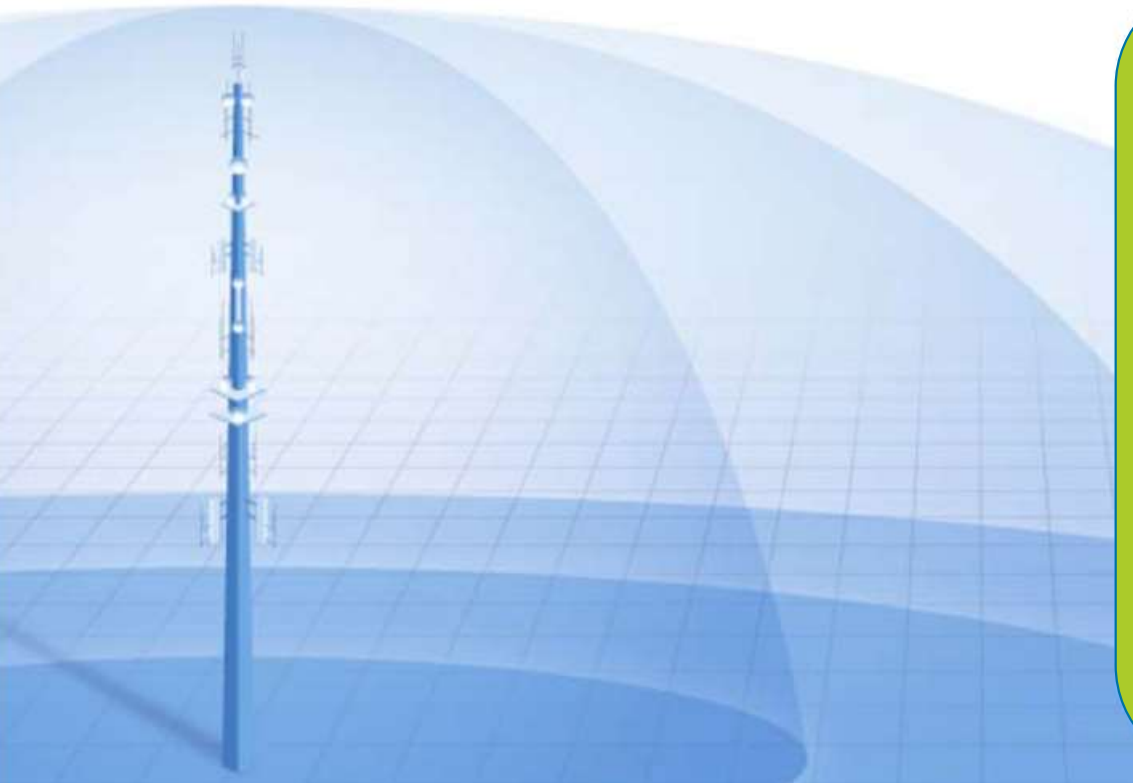
Technology Value Proposition



Coverage

Capacity

Power

Coexistence

Security

Choosing the Right Network for M2M

Capacity, Coverage, Cost-effective

Applications	Number of Devices	Latency Requirements	Cost/ Endpoint	Suitable Technology
Generation	10s	Low Latency	$$$$$	Fiber
Transmission Substation				
System Protection				
Distribution Substation	100s		$$$$	3G/4G
Network Backhaul				
Feeder Automation/Switches/Reclosers	1,000s			ONRAMP WIRELESS Connected by RPMA™
Volt/VAR: Cap bank controllers				
Circuit infrastructure sensing		Less latency sensitive – benefit from coordinated sense of time	$$$	
Overhead fault indicators (FCI)	10,000s			
Below ground assets (incl. FCI, transformer)				
Condition-based monitoring/Remote I/O	100,000s		$$	
Smart Transformer Monitoring		Least latency sensitive – benefit from coordinated sense of time		
AMR/AMI residential and commercial	1,000,000s			
Demand management in home and commercial			$	
In home networks				

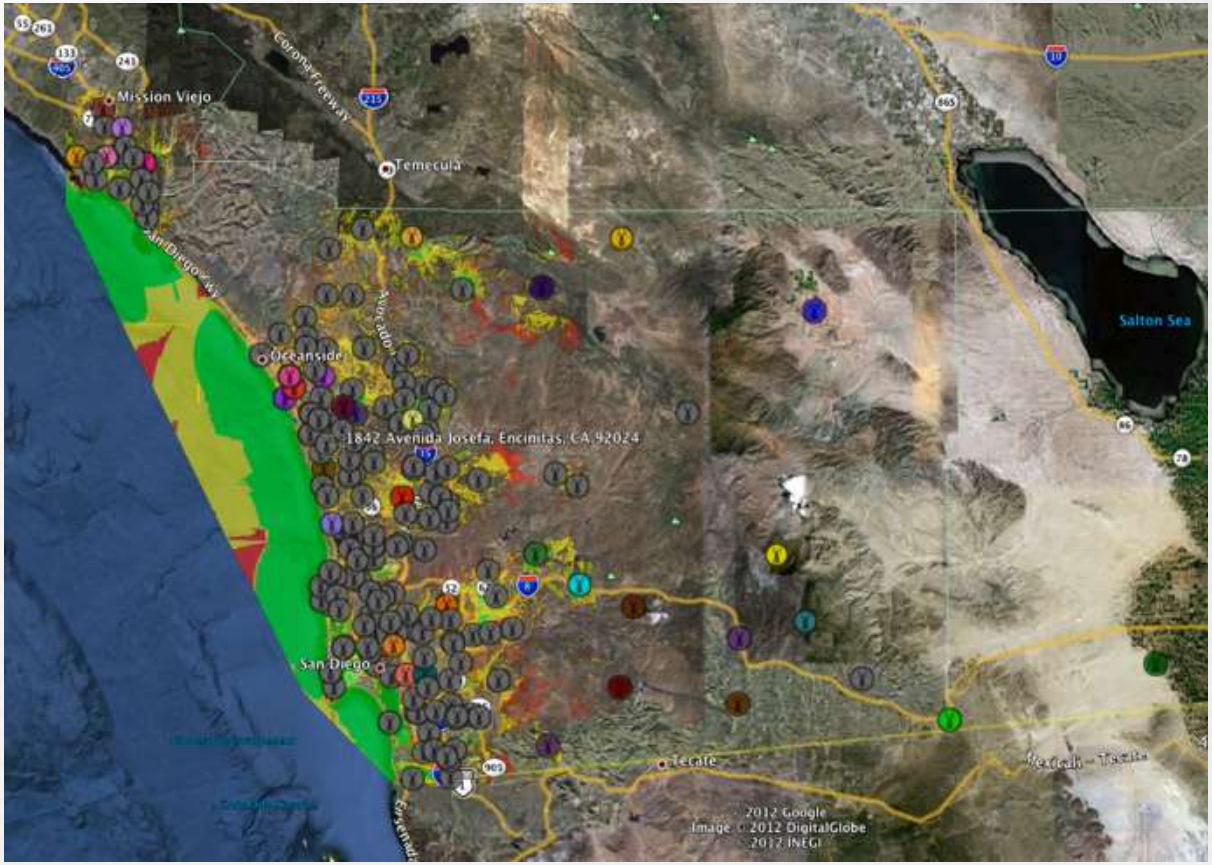
Network Coverage
Above Ground Coverage

Overhead Network Coverage

4,100 Square miles of territory are covered by 35 On-Ramp access points

Network Coverage
Underground Assets

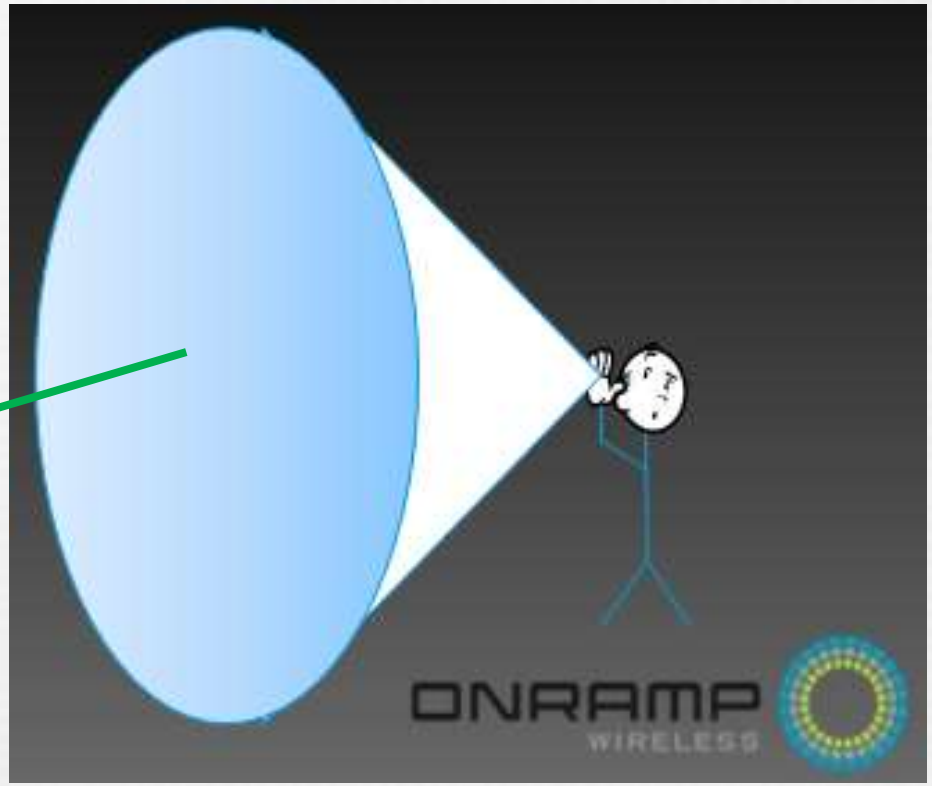
On-Ramp enables first below ground central grid automation solution for low voltage lines covering:
•185 APs covering critical circuits
•1,500 sq miles of circuits for SDG&E



Purpose-Built Link Budget

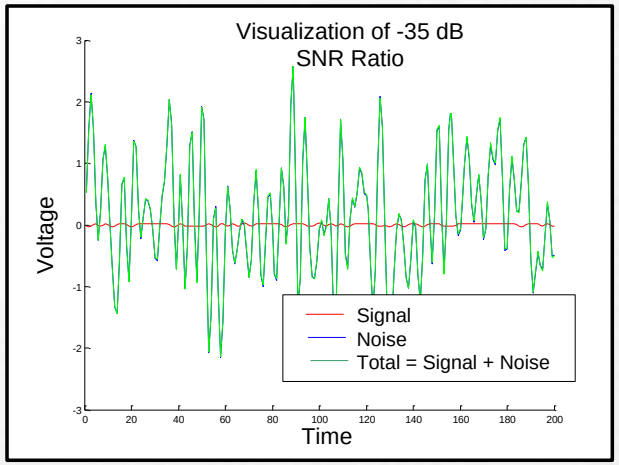
- Measures the ability of a communication system to close the link.

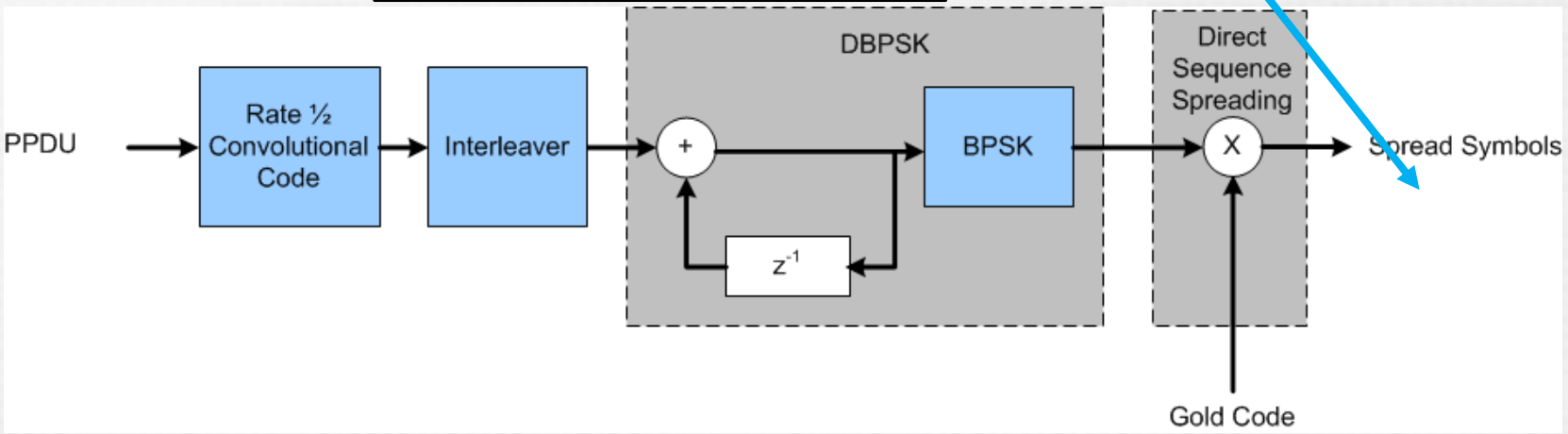
- Three Drivers:
  - Transmit Power
  - Antenna Gain
  - Receiver Sensitivity



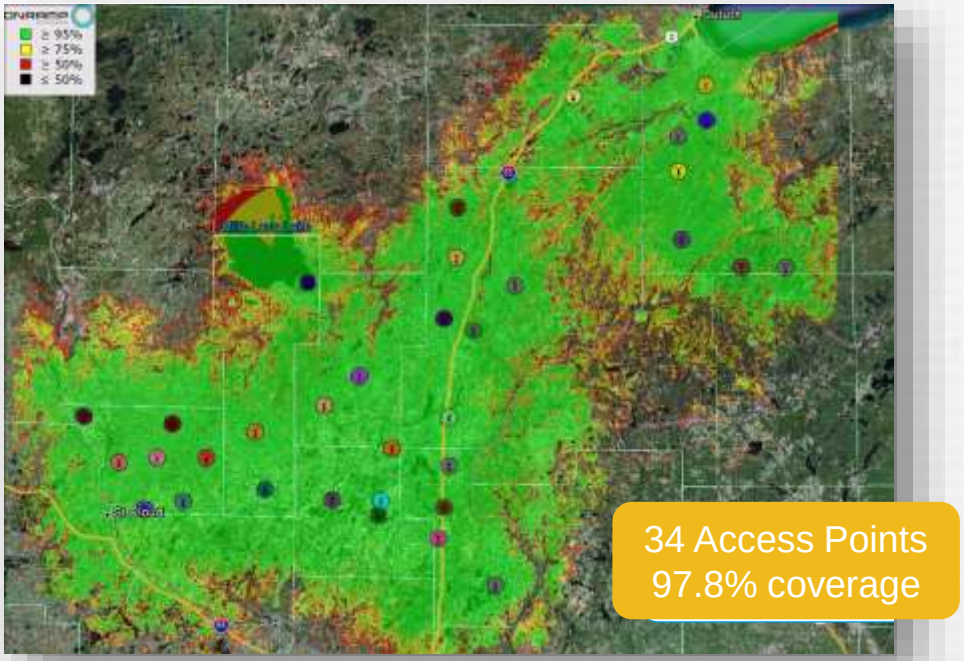
Receiver Sensitivity using DSSS

- Spreading factors up to 8192 chips/symbol to get up to 39 dB of **processing gain – 172 dB of Link Budget – Largest in Industry.**
- Receiver sensitivity is -133 dBm on downlink and -142 dBm on uplink





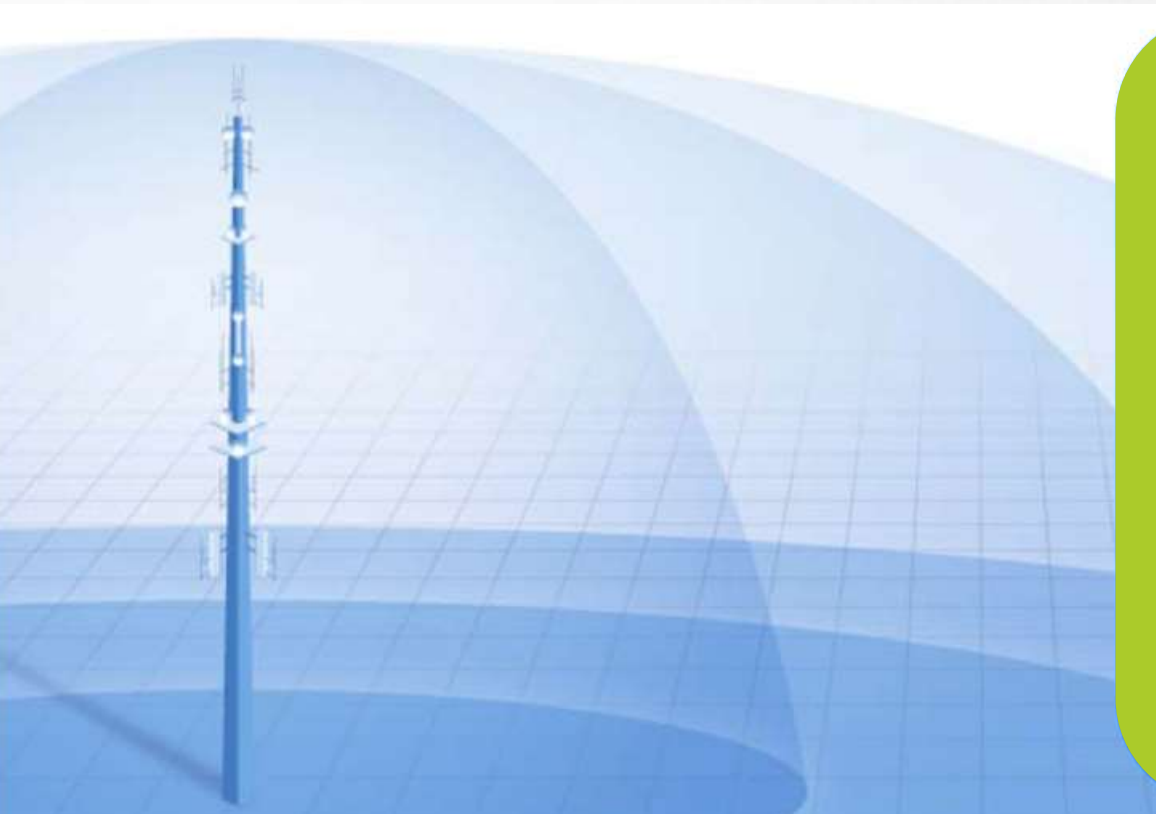
Star Topology
Allows Accurate Propagation Planning



- Maps are created that gives a very high degree of confidence of coverage.
- Accurate techniques model the effects of:
  - Terrain
  - Clutter
  - Margin (for high probability of coverage)
  - Interference
  - Dynamic Link
  - Access Point Macro-Diversity
  - Node-side Antenna Diversity

See: "*Smart Grid Automation for Underground Utility Assets Wireless System Trade Study*" as prepared for the Dept. of Energy by ORW for more details.

Technology Value Proposition



Coverage

Capacity

Power

Coexistence

Security

Purpose-Built Capacity

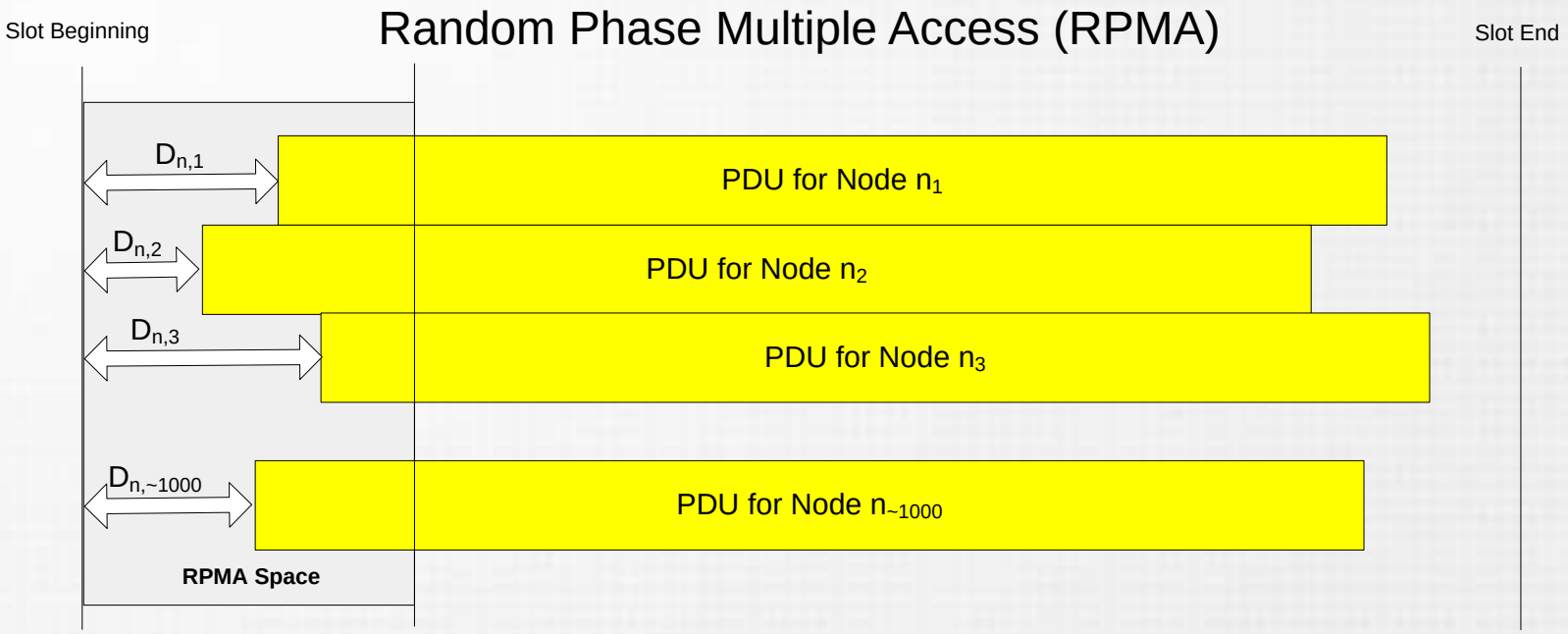
- **Uplink (Node → AP)**
  - AP can receive **100 MBytes/day** in steady-state using RPMA
  - Can service >2000 nodes simultaneously, e.g. outage flood

Application	Update Interval	Data/Day	# per AP*
Electric AMI Meter	15 min interval data	2.4 KB	20,000+
Gas Meter	2 per day	140bytes	90,000+
Fault and line sensor	1 per day	16 bytes	3,000,000+
Smart Transformer	24 per day	2.4 KB	40,000+

All at the same time!

- **Downlink (AP → Node)**
  - Up to **72 MBytes/day** of unicast user data
  - Up to **144 kBytes/day** of multicast user data
  - Up to **72 kBytes/day** of broadcast user data

Purpose-Built Capacity



(12) **United States Patent**
Myers

(10) **Patent No.: US 7,782,926 B2**
(45) **Date of Patent: *Aug. 24, 2010**

(54) **RANDOM PHASE MULTIPLE ACCESS COMMUNICATION INTERFACE SYSTEM AND METHOD**

(75) Inventor: **Theodore J. Myers**, San Diego, CA (US)

(73) Assignee: **On-Ramp Wireless, Inc.**, San Diego, CA (US)

5,297,162	A	3/1994	Lee et al.
5,353,300	A	10/1994	Lee et al.
5,359,624	A	10/1994	Lee et al.
5,392,287	A	2/1995	Tiedemann et al.
5,404,375	A	4/1995	Kroeger et al.

(Continued)

FOREIGN PATENT DOCUMENTS

KR	20020001071	1/2002

$$E[S_{RX}] = \frac{N_0 \cdot \mu_{SNR}}{G - (N_{TX} - 1) \cdot \mu_{SNR} \cdot e^{\frac{1}{2}\left(\frac{\sigma_{SNR}}{10log_{10}(e)}\right)^2}}$$

RPMA Capacity

- The loading of RPMA can be expressed mathematically as a loss of link budget:

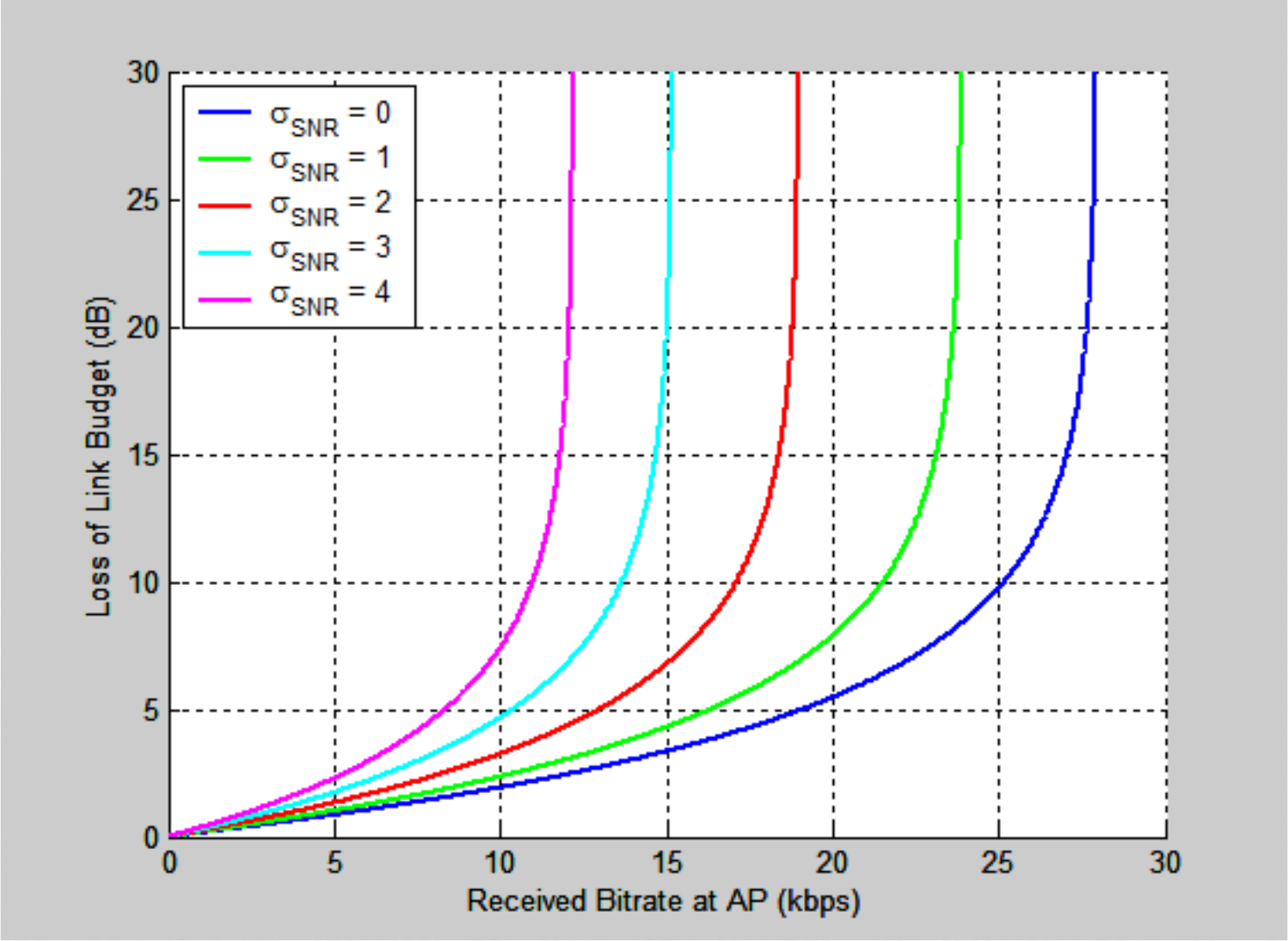
$$L_{dB} = 10log_{10}(E[S_{RX}]) - S_0$$

- Where E[SRX] is the expected receiver sensitivity which, in turn, can be expressed as:

$$E[S_{RX}] = \frac{N_0 \cdot \mu_{SNR}}{G - (N_{TX} - 1) \cdot \mu_{SNR} \cdot e^{\frac{1}{2}\left(\frac{\sigma_{SNR}}{10log_{10}(e)}\right)^2}}$$

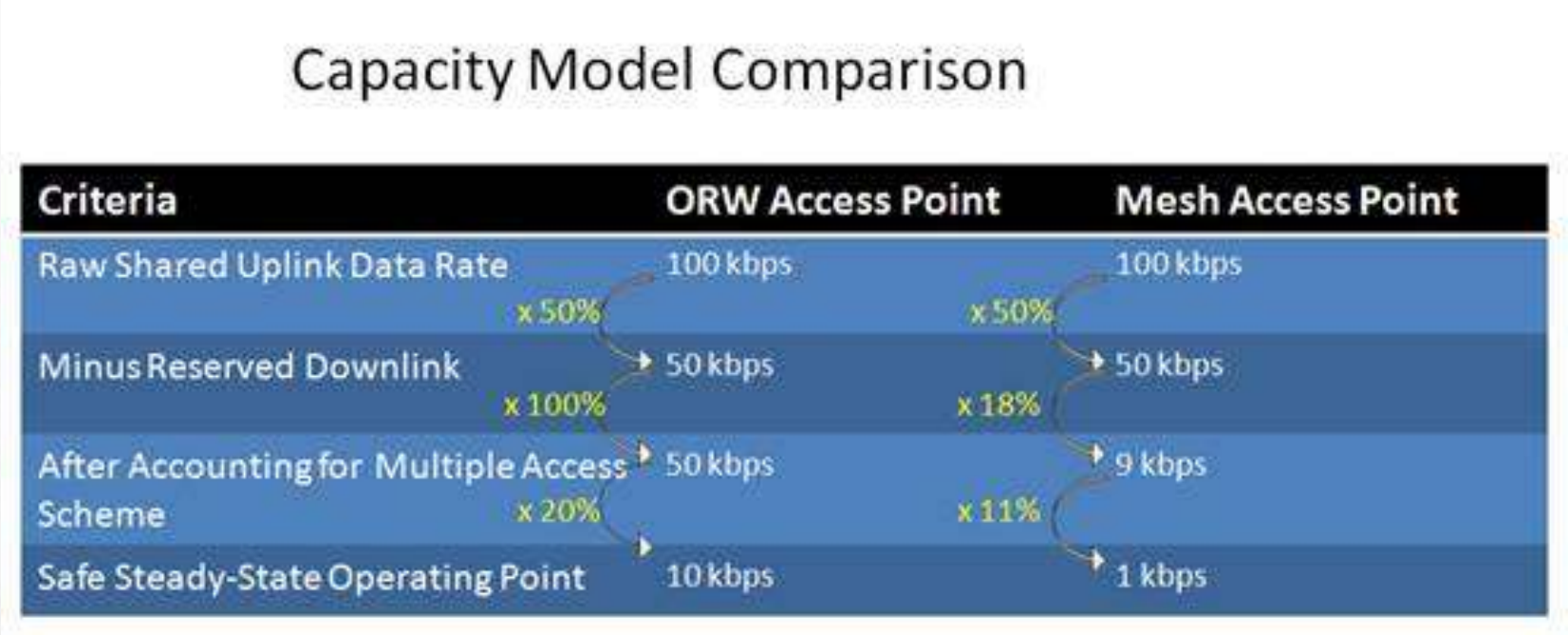
- The parameters in this equation are as follows:
  - NTX = The number of transmitted physical layer packets. This is related to the number of received packets, NRX through the packet error rate, i.e. Nrx = Ntx*(1-PER).
  - G = The maximum processing gain = 8192.
  - N0 = The ambient noise floor at the AP which includes thermal noise and other out-of-system interference.
  - mu_snr = The target SNR for the power control loop. This is nominally set to 5.5 dB, however, the user can increase it to reduce the packet error rate.
  - sigma_snr = The variance around target SNR after power control due to channel fading, estimation errors, and calibration errors.
  - S0 = The receiver sensitivity with no loading at the AP = -142 dBm.

RPMA Capacity

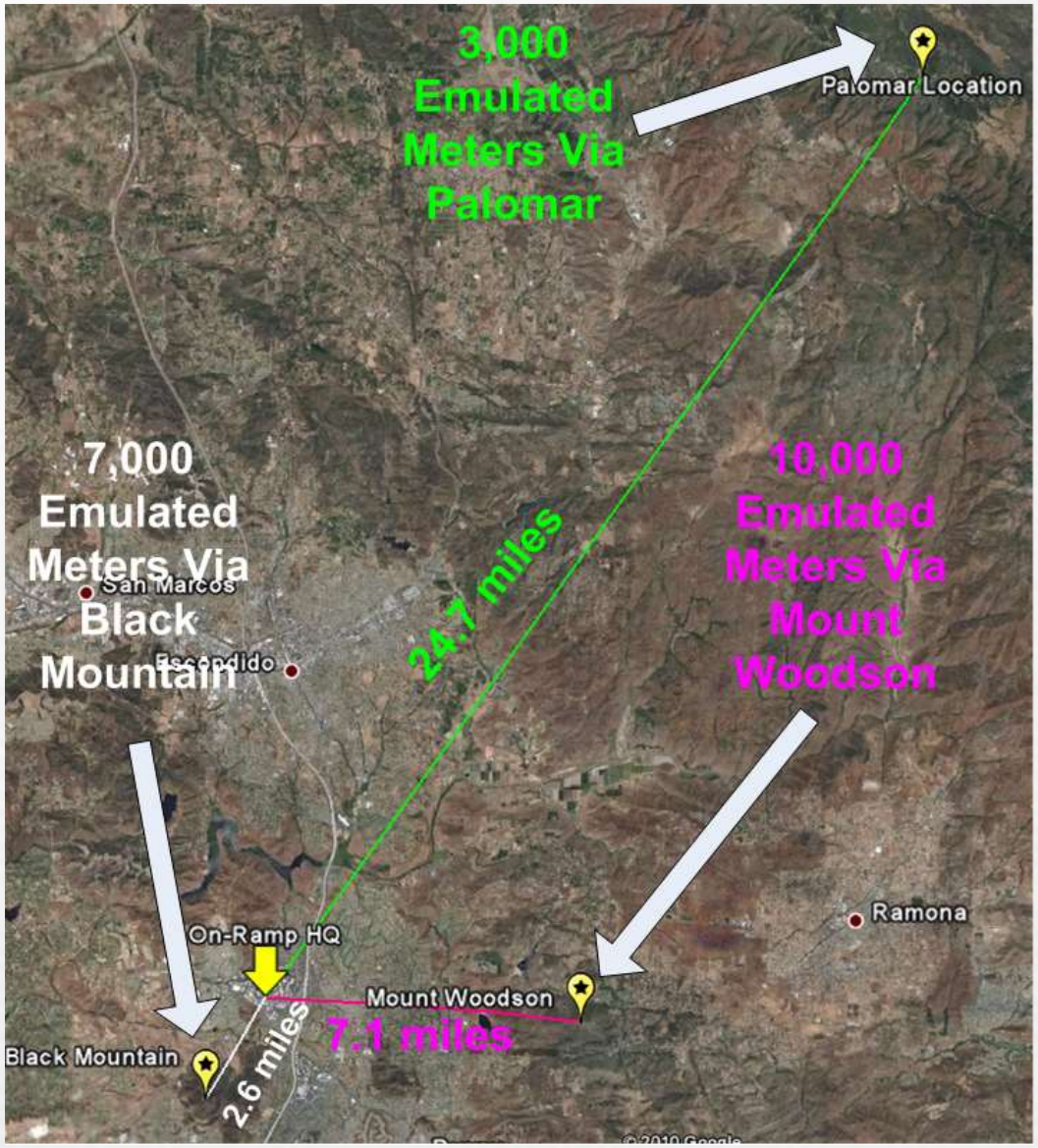


Capacity Comparison

- On-Ramp Access Point has an order of magnitude more capacity!
- On-Ramp Access Point has two orders of magnitude more spectral efficiency!



Over-the-Air (OTA) Meter Emulation System



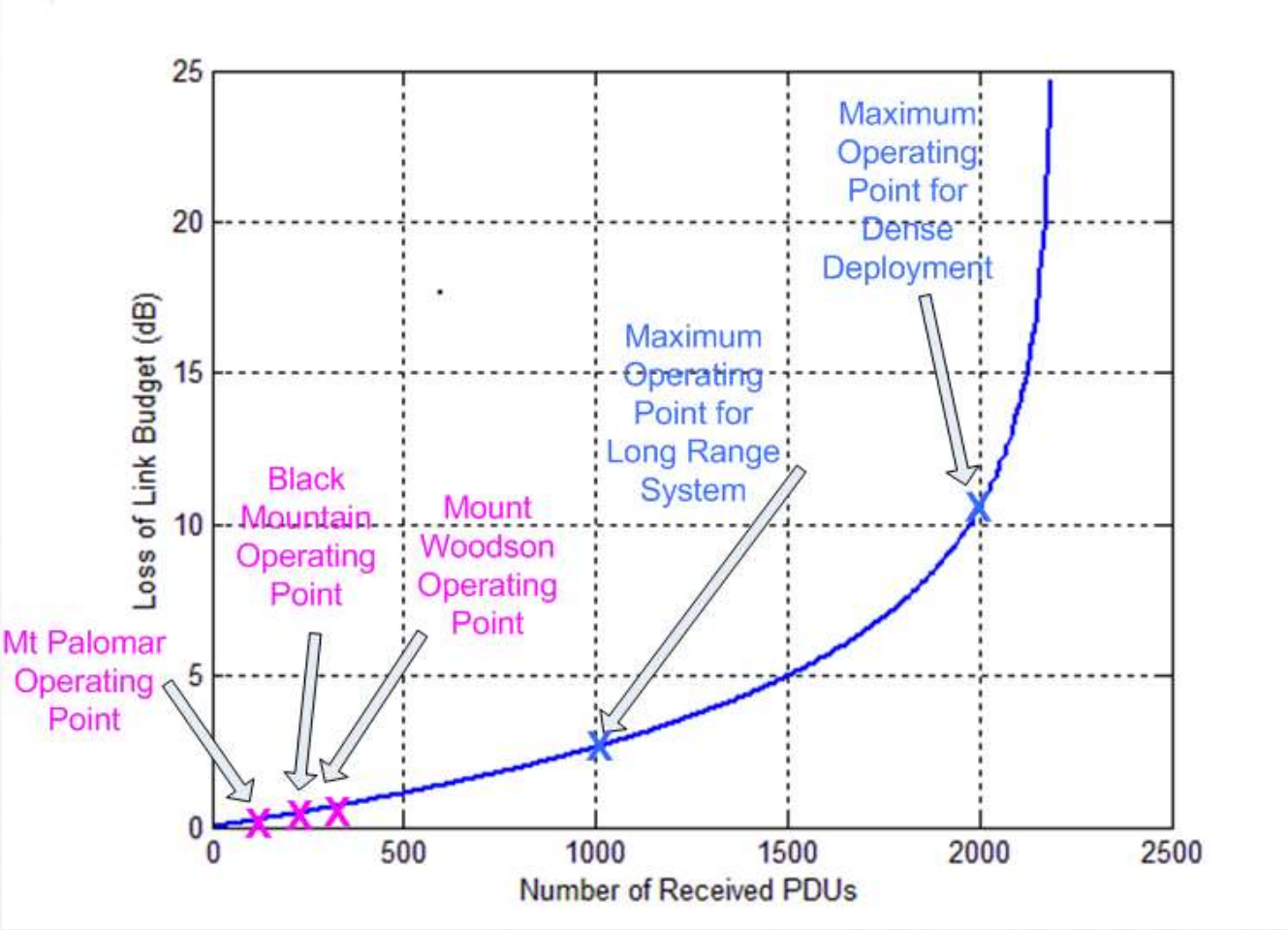
3 Mountaintop Access Points

- Mount Woodson (7.1 miles away from office)
- Black Mountain (2.6 miles from office)
- Mount Palomar (23.7 miles away from Office)

1000 Nodes in Office

- 20 dB loss through tinted windows
- Emulating 20,000 electric meters
- Assumes 2.4 kbyte per day per meter
- Represent ~10% of the capacity of the system.
- **3 Access Points are capable of supporting 200,000 electric meters**

Long Range with High Capacity



Current Meter Demonstration Operating at Less than 10% Capacity

Technology Value Proposition

Coverage

Capacity

Power

Coexistence

Security

Purpose-Built Power Efficiency

- Ultra-efficient protocol designed for battery powered devices
  - Nodes in extremely low power “deep sleep” mode most of the time
  - Nodes are awake just long enough to transmit and receive data
  - Nodes transmit only at minimum processing gain required to close the link, i.e. they Tx for the shortest period of time possible
  - Nodes have a very efficient network acquisition
  - Nodes do not have to be active to repeat traffic
- On-Ramp has developed a highly efficient ASIC implementation designed to support long battery life
  - MicroNode
  - More ultra low power integrated products on the roadmap

Long Battery Life Sensors on Same System

>3000 Deployed In San Diego County

SEL

10-15 Year Battery Life

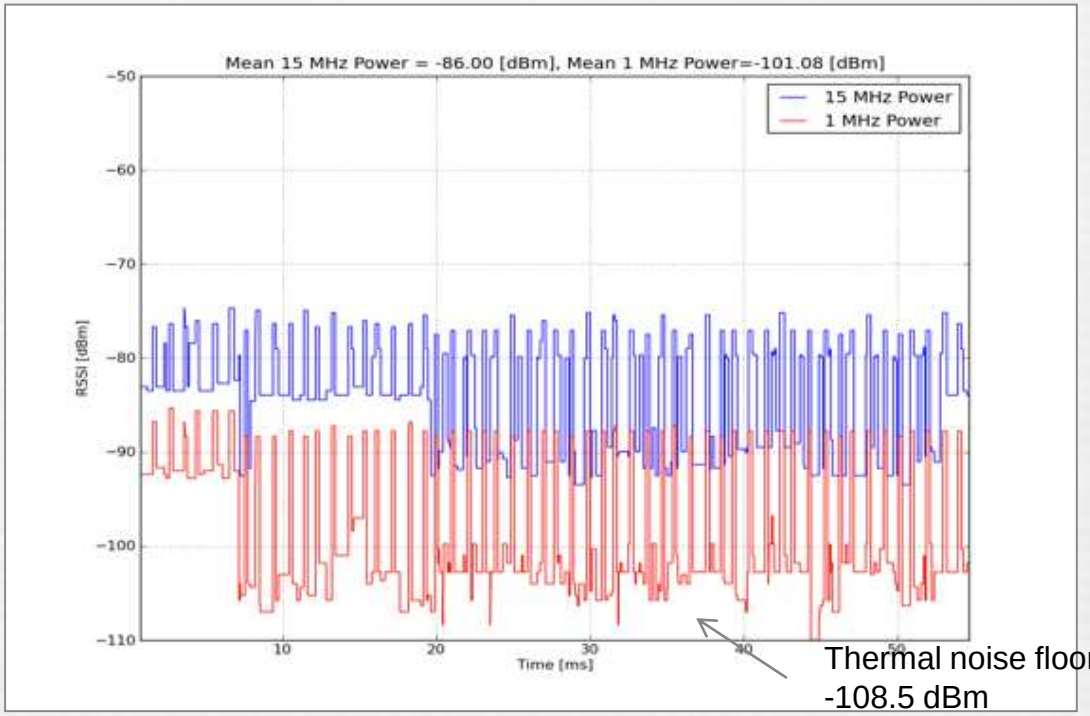
Good for Rural Lines: No need to harvest power from lightly loaded lines.

Technology Value Proposition

Coverage
Capacity
Power
Coexistence
Security

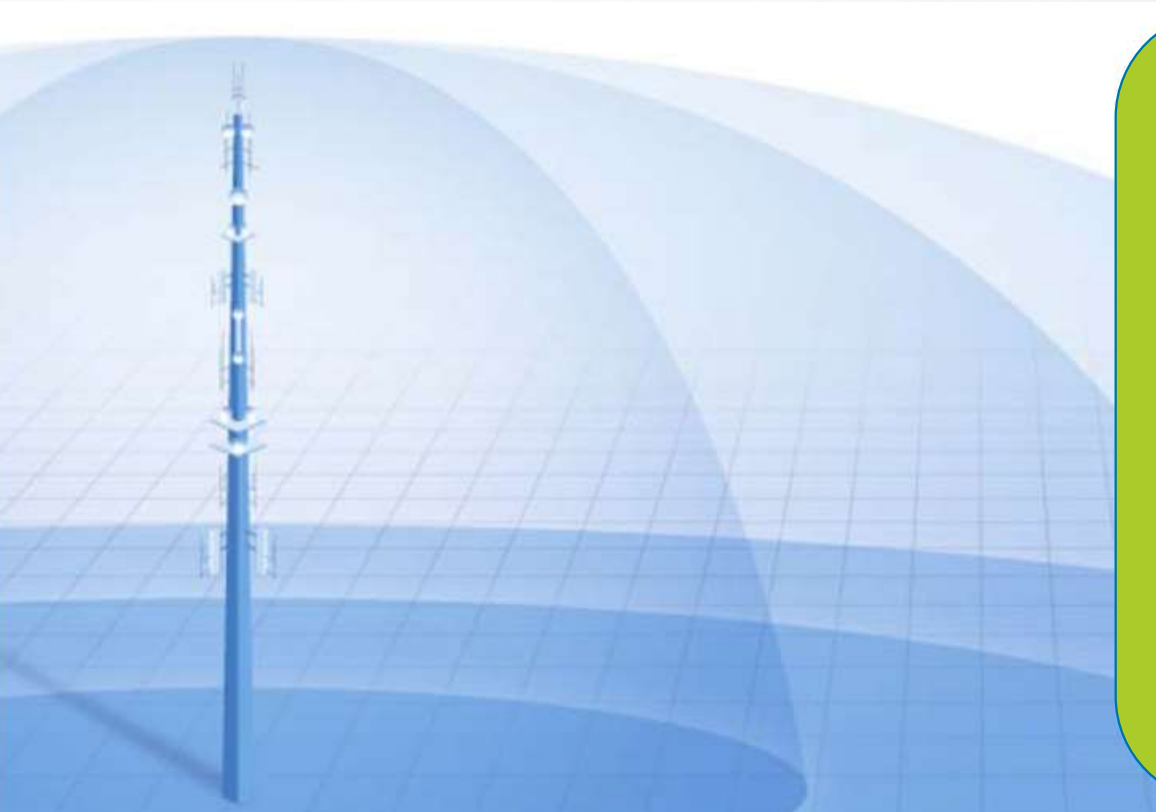
Importance of Co-existence

- Mount Woodson site has significant noise floor elevation
- Dynamic in-band energy from other ISM band systems
- Presented in IEEE 802.15.4k as document DCN 15-11-0074-00-004k.
- ULP performance is able to overcome these interference levels and operate robustly.



Thermal noise floor
-108.5 dBm

Technology Value Proposition



Coverage

Capacity

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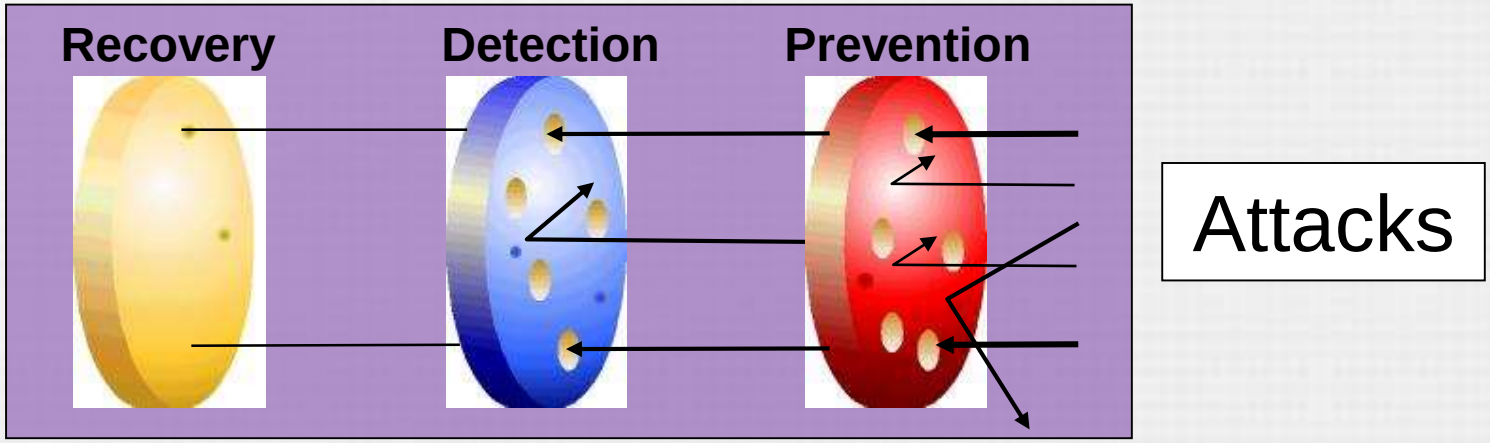
Purpose-Built Security

- Security for Low Bandwidth Applications
  - Security not bolted on but part of the fundamental design
  - Mechanisms designed for power constrained, low bandwidth networks with a star topology
  - NIST approved security until 2030 (20+ years of life)

- Comprehensive approach to information security



Security Summary

- Security is field proven and deployed
- Compliant with the latest cyber security guidelines and standards
  - Follows NERC CIP 002-009 and NIST SP 800-53 guidelines for critical cyber assets
  - Meets FIPS 140-2 Level 1 for communications device
  - Follows guidelines prescribed in NISTIR-7628.
  - Design based on NIST/FIP publications including NIST SP 800 series and FIPS 197
  - Information security integrated into Software Development Life Cycle following NIST SP 800-64 guidelines
- Tested and approved
  - Security Audit performed by independent 3rd party assessment companies
  - Passed SDG&E Security Audit and SDG&E hired 3rd party penetration testing

Vertical Industries
Relevant to M2M Communications

Utilities	Industrial Automation	Location Based Services	Infrastructure and Security
○ AMI Electric Meters ○ Gas & Water Meters ○ Smart Transformers ○ Fault Circuit Indic. ○ Distribution Automation ○ Building HVAC Automation	○ Leak Detection ○ Pressure Sensors ○ Temp. Sensors ○ Vibration Sensors ○ Chemical Sensors ○ Radiation Sensors	○ First Responders ○ Military Personnel ○ Vehicle Fleets ○ Railroad Freight ○ Shipping Containers ○ Industrial Campus and Field Operations	○ Surveillance and Security ○ Border Control ○ Bridge Monitoring ○ Fire Detection ○ Landslide Monitoring

Transportation Asset Tracking
Train Yard

Challenge:
Monitoring and tracking of rail yards, vehicles, locomotives as well as expansion into cargo sensing

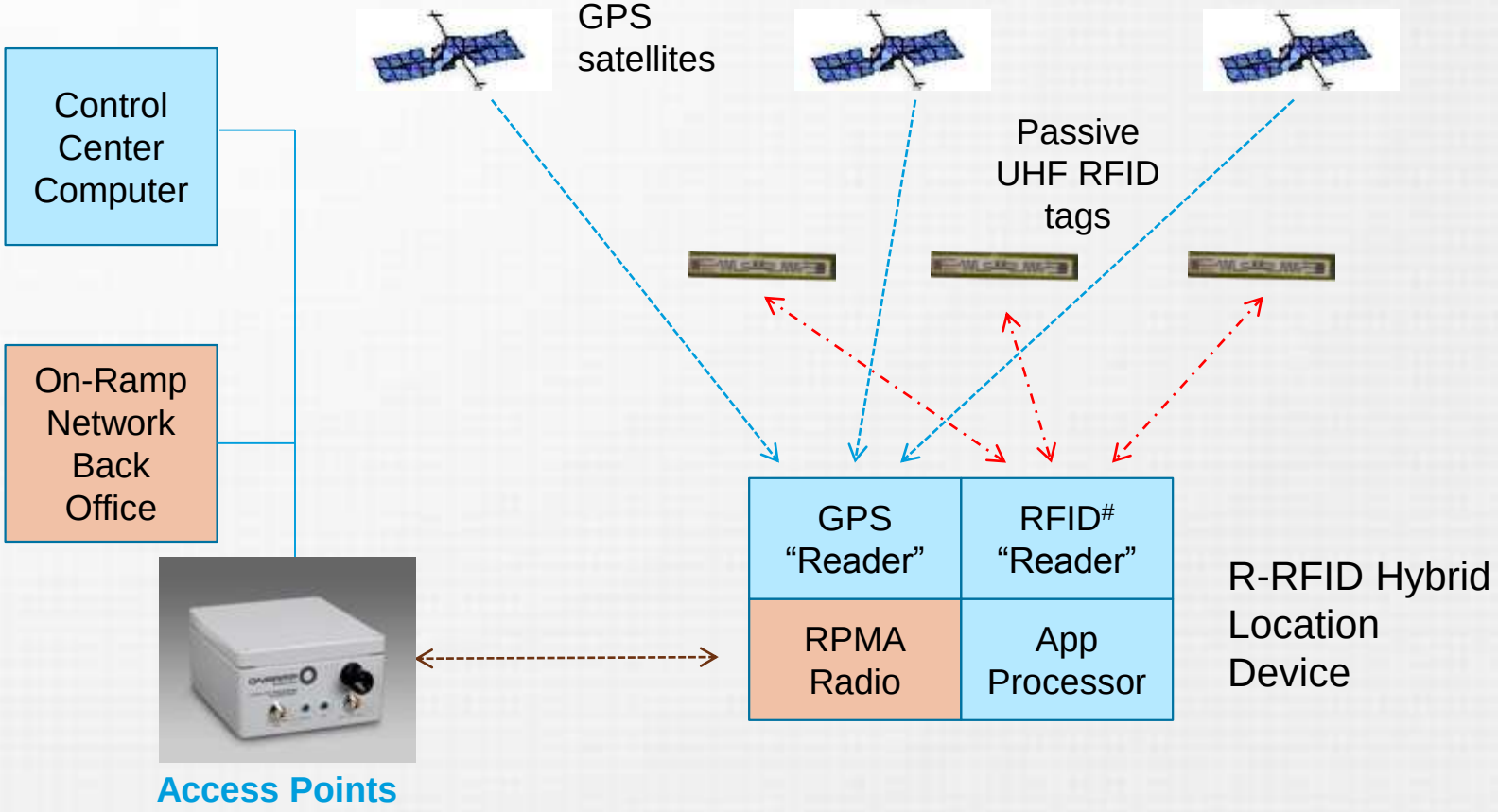
Solution:
On-Ramp enabled GPS Tracker

Partners:
MagellaGlobal Geospatial and endpoint OEM

Indoor High Accuracy Tracking

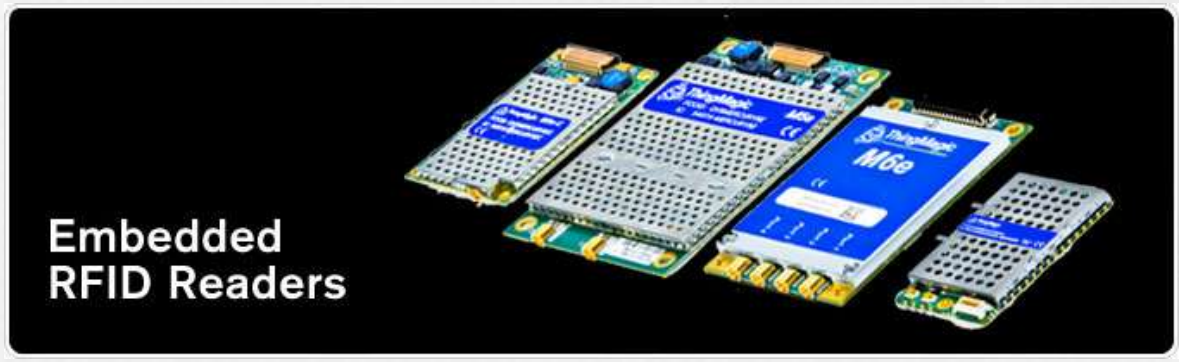
- Problem: Precision Indoor tracking a challenge for existing position technologies
  - GPS signals lose accuracy indoors
  - Communications based approaches not accurate and connectivity in buildings a challenge
- A provider has developed a Real Time Location System using On-Ramp Wireless' networking technology
  - RFID location technology works in any environment with Passive UHF RFID location tags, Indoors or Outdoors
- On-Ramp's RPMA technology ensures that location/status reports penetrate the most challenging RF environments

“R-RFID” System Diagram
Integrated GPS for Global Outdoor Location

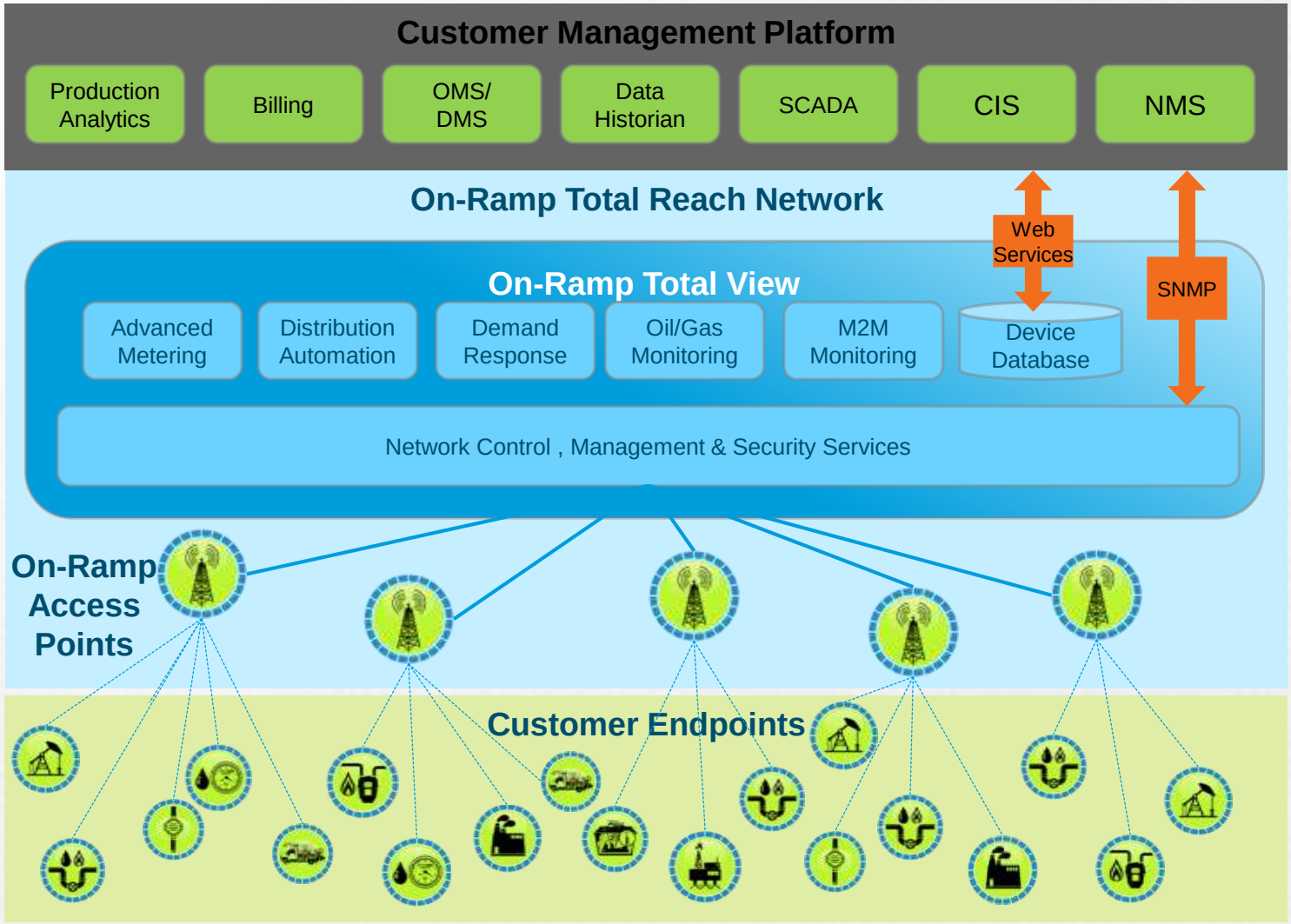


Mobile Location Sensors

- R-RFID and On-Ramp location aware mobile sensors can be used for;
  - Real time personnel safety systems
    - Personnel alert/warning/check-in
    - Location of all workers at all times
    - Man down indication, worker initiated SOS
  - Automatic time sheet
  - Work flow management
  - Compliance, inspection
  - Asset tracking



On-Ramp Total Reach Solution Architecture



Key Benefits
Deploying an RPMA-based Solution

Requirement	On-Ramp Total Reach Solution
Actionable Information	Rich data driving insights, decisions previously unattainable Designed specifically for M2M communications Reliable 2-way communications
Pervasive Coverage	Wide-area reach in extremely challenging RFP environments, in challenging metal plants Above and below ground connectivity Up to 400 sq miles of non-line-of-sight coverage from a single AP
High Capacity	High capacity, low power RPMA™ Platform All applications supported by a single network Monitor any sensor
Flexibility	Deploy 300 mi^2 of coverage per day Deploy applications as business requires Ultra low power consumption supports 10-15 year battery life Globally available spectrum
Security	3rd-party verified security Compliance with NIST security guidelines


ONRAMP
WIRELESS
Thank You!