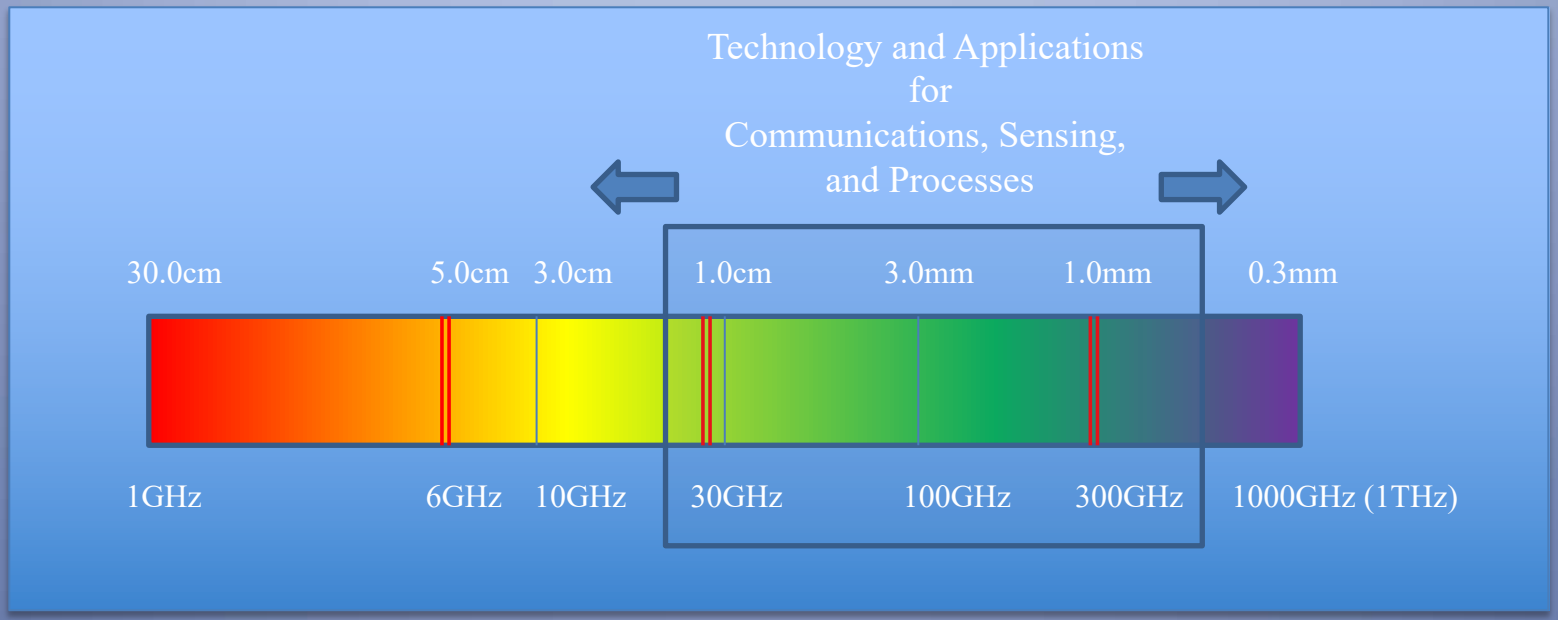
IEEE IoT Vertical and Topical Summit

"The Internet of Things and the mmWave Frontier: an Overview"



Adam T. Drobot, Wayne, PA 19087

San Antonio, Texas January 26th, 2020

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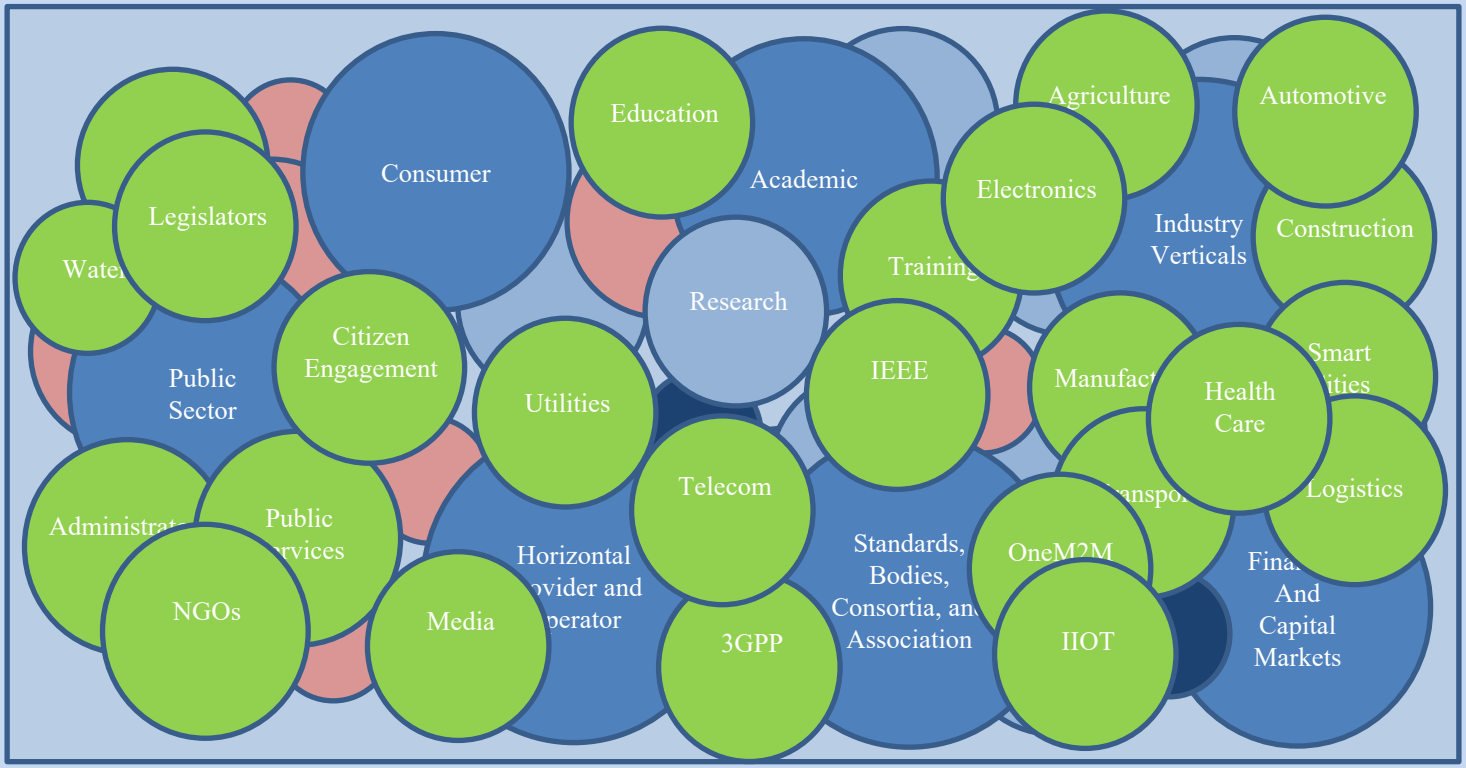
Outline

- *The Internet of Things and the mmWave Frontier*
  - *A bit about:*
    - *The Internet of Things (IoT)*
  - *A bit about*
    - *mmWave and THz Technology Opportunities*
  - *Summary and Discussion*

A bit about: The Internet of Things

A Very Complex Eco-System With Many Stakeholders



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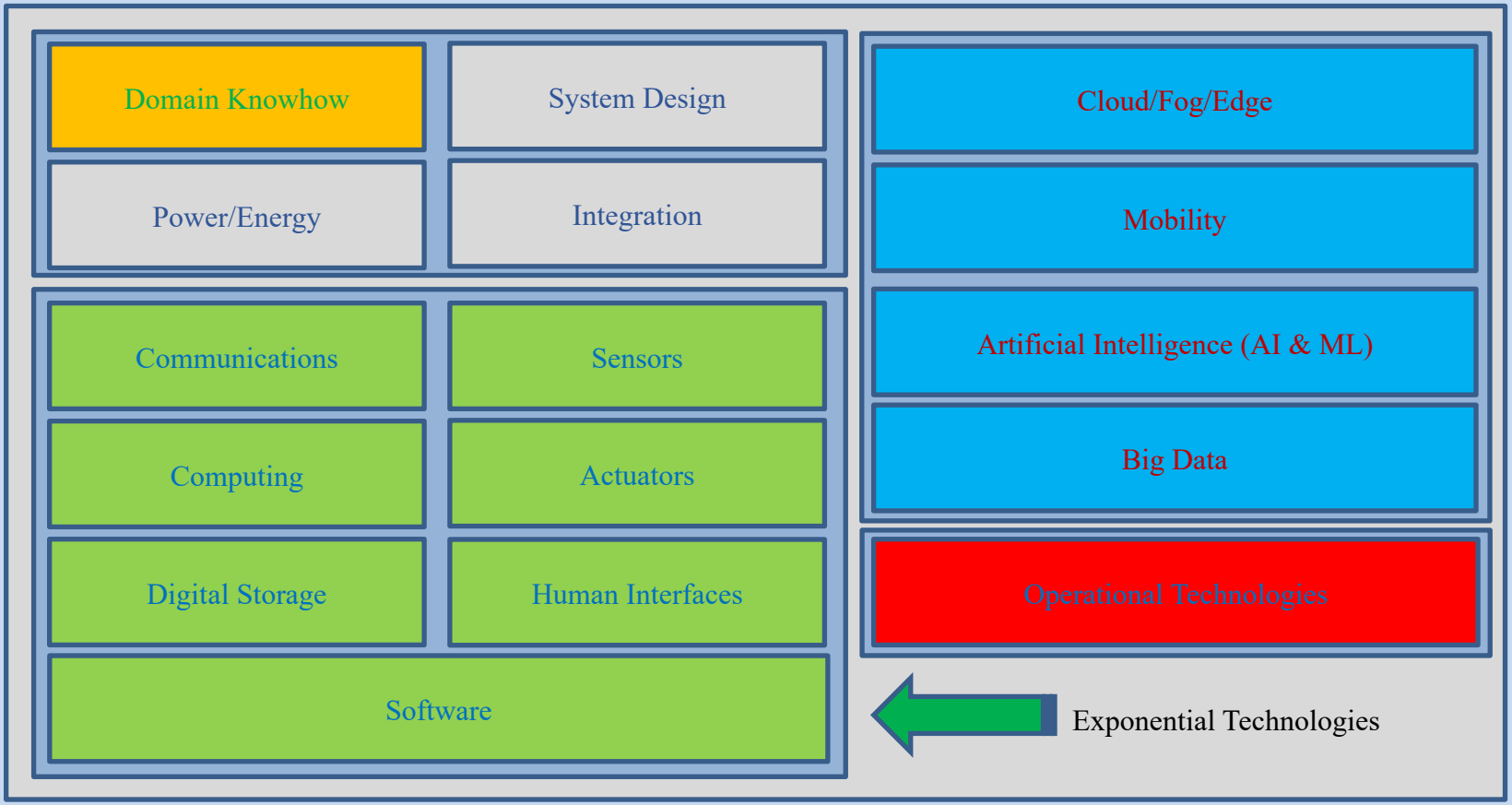
A bit about IoT



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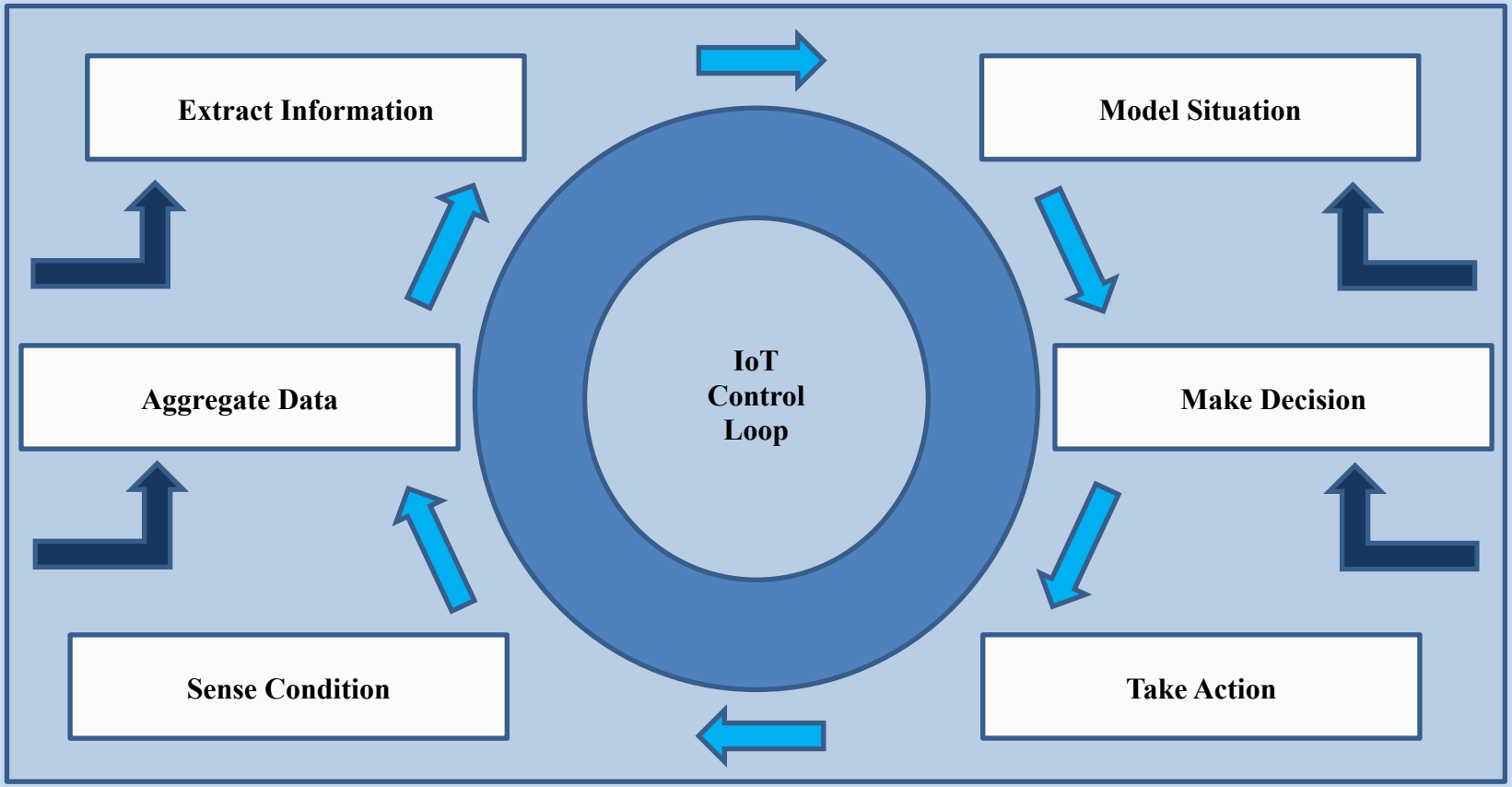
A bit about: The Internet of Things



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A bit about: The Internet of Things

Value and
Level of
Implementation

How: Prescriptive

Automation in
Dealing with
Problems

Optimized
Solutions

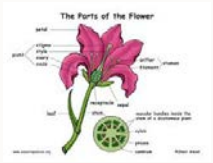
When: Prognostic

Predicting when
Problems
Will happen

Why: Diagnostic

Understanding
Root Causes

What: Descriptive



Situational
Awareness

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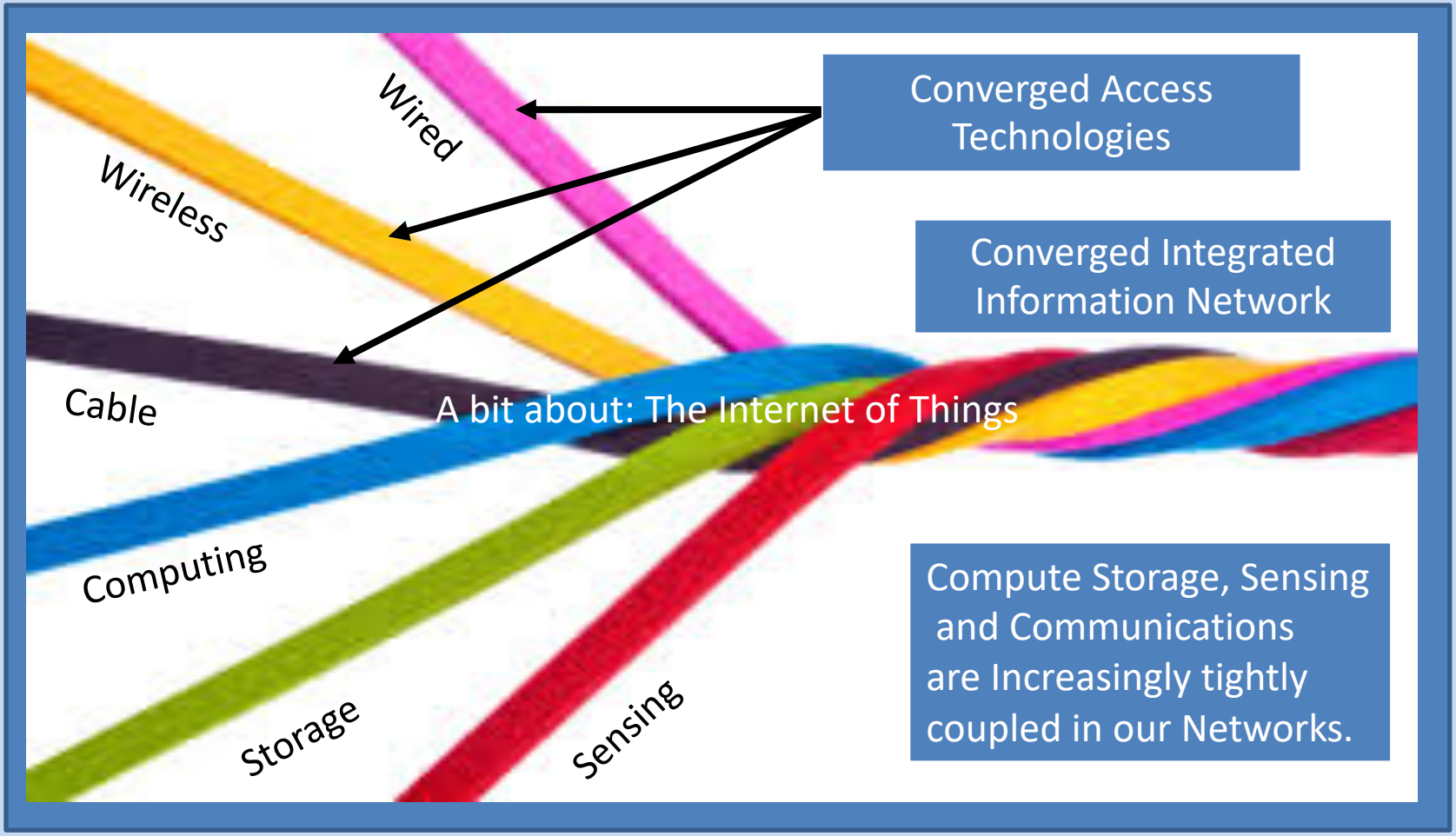
A bit about: The Internet of Things



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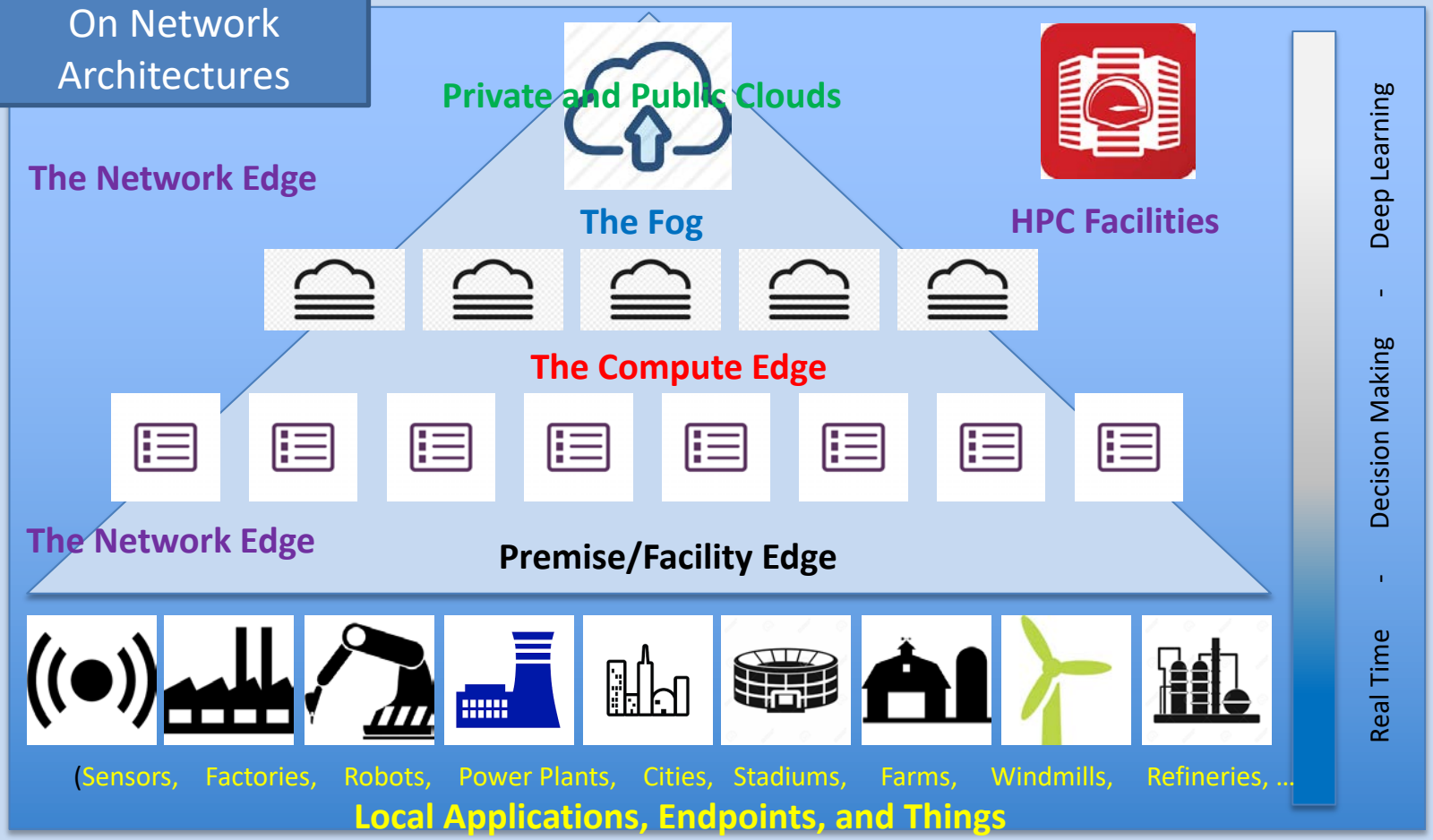
A bit about IoT

The Impact of Convergence On Network Architectures



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A bit about IoT

Vertical Specific Applications

Core Multi-Vertical Platform

Common Components

- Computing
- Storage
- Connectivity
- Interfaces (APIs)
- Actuators
- Sensors
- Software, Data Management

Core Services

- Directory, Naming
- Billing
- Provisioning, Activation
- Deployment
- Monitoring, Optimization
- Maintenance
- Application Enablement
- Intellectual Property

End-End Attributes

- Security/Privacy
- Availability
- Reliability
- Scaling
- Distribution

Performance

- Latency
- Jitter
- Bandwidth
- Capacity

Vertical Specific End-System Implementations

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A bit about IoT

Vertical Specific Applications

Enumerating the Space that IoT Spans		
Common Components	1,000,000s	Across Building Blocks
Core Services	100,000s	For Application Types
Performance Parameters	100,000s	Over all Verticals
Attributes	10,000s	For Range of Use Cases
Multiple (Hopefully few) Architectures Needed to Span the Space		

Vertical Specific End-System Implementations

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A bit about: The Internet of Things

- *Its about Economics!!!!*

** World Bank Estimates in current $ Terms

GDP Figures and Trends			
Year	World	United States	China
2016	$75.641 Trillion	$18.569 Trillion	$11.199 Trillion
2010	$62.220 Trillion	$14.964 Trillion	$ 6.101 Trillion
2000	$41.016 Trillion	$10.285 Trillion	$ 1.211 Trillion
1990	$27.539 Trillion	$ 5.980 Trillion	$ 0.361 Trillion

- *The target cost of a node ~ $3.00-$10.0*

Cost Impact of IoT Deployment			
Nodes/Cost per Node	$10.00	$100.00	$1000.00
25 Billion	$0.250 Trillion	$2.50 Trillion	$25.0 Trillion
75 Billion	$0.750 Trillion	$7.50 Trillion	$75.0 Trillion
150 Billion	$1.500 Trillion	$15.0 Trillion	$150 Trillion

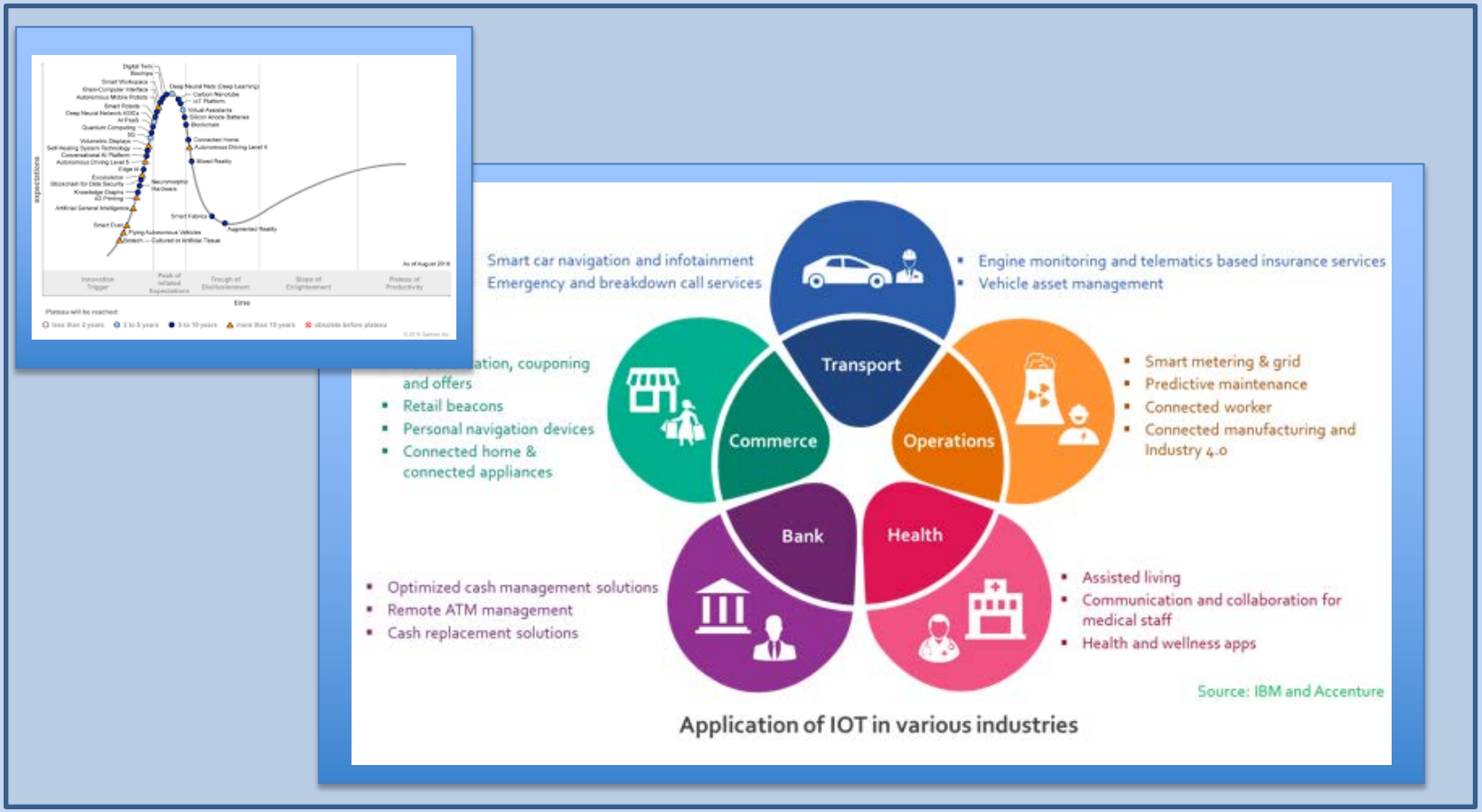
A bit about: The Internet of Things

- *What's in a Node? How to get the cost down to the ~ $3.00-$10.0 Target?*

Capital Costs	*Operating Costs*

• *Goods and Components*
• *Integration*
• *Installation*
  • *Labor*
• *Test and Validation*
• *Training*
• *Facilities*
• *Upgrades*
	• *Contracted Services*
	  • *Communications*
	  • *Cloud*
	  • *MRO*
	• *Staffing*
	• *Maintenance*
	• *Unforeseen Repairs*
	• *Storage*
	• *Facilities*
	• *Upgrades*

A bit about: The Internet of Things



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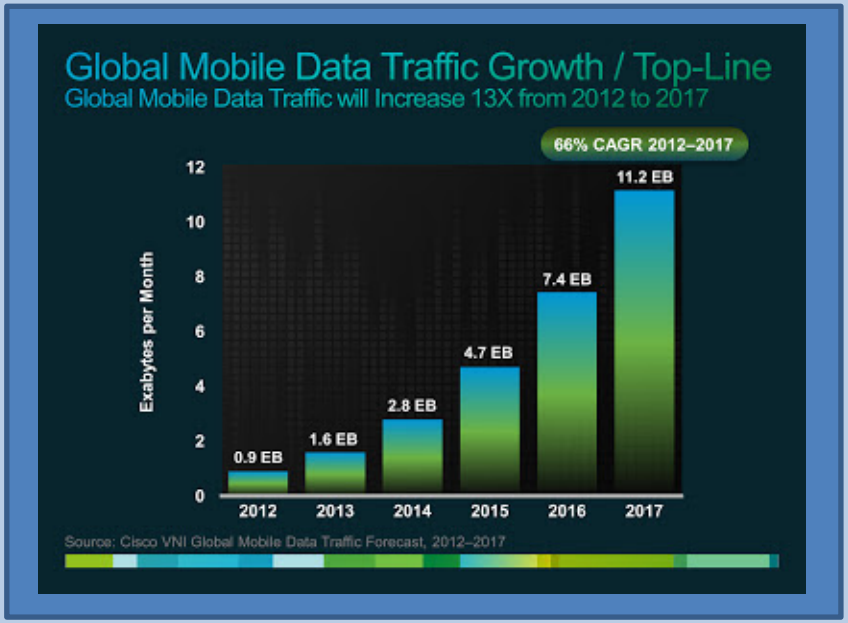
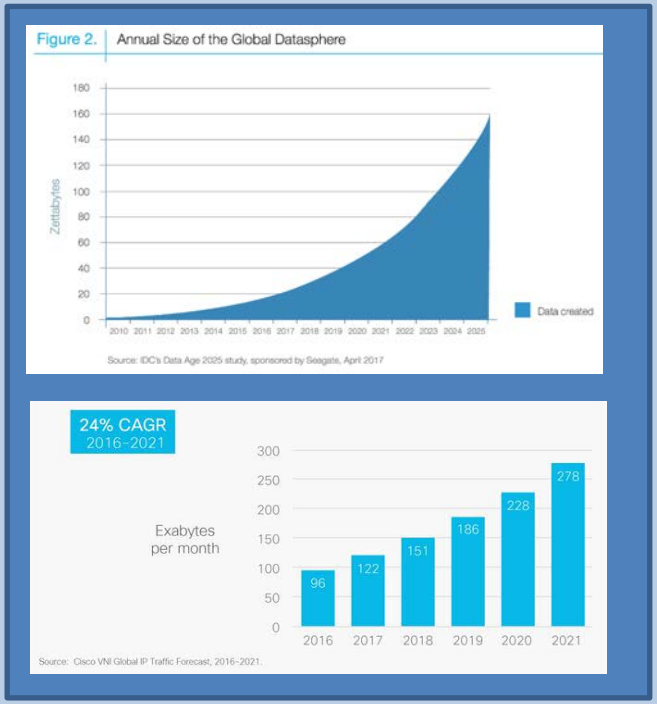
A bit about: The Internet of Things

Growth in Data Traffic



Source: Cisco



Source: Data Age 2025 Study - IDC

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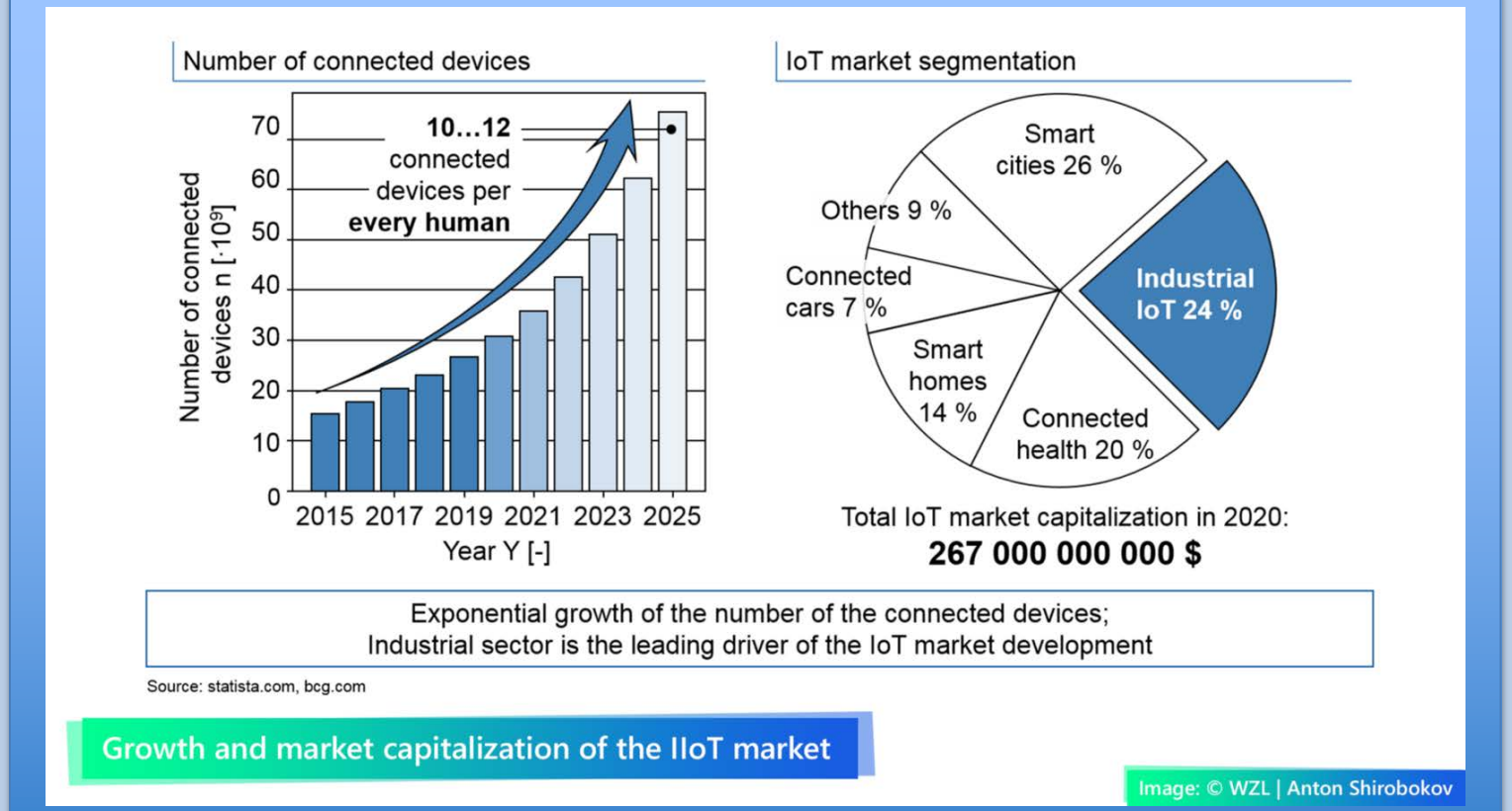

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A bit about: The Internet of Things

Trends for 2019: Gartner defines a strategic technology trend as one with substantial disruptive potential that is beginning to break out of an emerging state into broader impact and use; or as a trend that is rapidly growing with a high degree of volatility, and that will reach a tipping point over the next five years.

Trend No. 1: Artificial Intelligence (AI)
Trend No. 2: Social, Legal and Ethical IoT
Trend No. 3: Infonomics and Data Broking
Trend No. 4: The Shift from Intelligent Edge to Intelligent Mesh
Trend No. 5: IoT Governance
Trend No. 6: Sensor Innovation
Trend No. 7: Trusted Hardware and Operating System
Trend No. 8: Novel IoT User Experiences
Trend No. 9: Silicon Chip Innovation
Trend No. 10: New Wireless Networking Technologies for IoT

A bit about: The Internet of Things

Important Issues

1. For economic viability IoT is highly dependent on infrastructure – the use of common services available for multiple purposes – power, computing, connectivity, etc. This includes connectivity and now "sensing".
2. The pattern for wireless connectivity has been built out to maximize population coverage. There are many IoT Application Verticals that require both mobility and Area Coverage. Examples are Agriculture, Mining, Natural Resource Management, Connected Vehicles, Emergency Services, Healthcare, etc.
3. Digitizing the Planet – as a source of knowledge and as a critical resource for responsibly managing what we have.

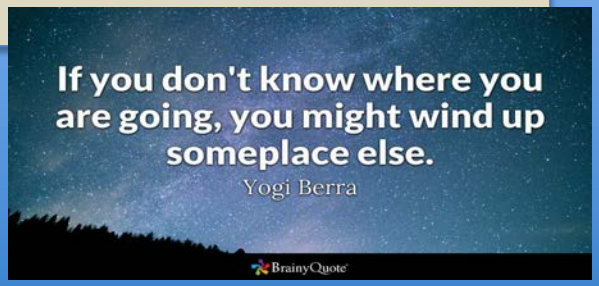
A bit about: mmWave and THz Technology Opportunities

Yogi Berra

"In theory there is no difference between theory and practice. In practice, there is!"

"You better cut the Pizza in four slices because I am not hungry enough to eat six."

"You can observe a lot by watching!"



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A bit about: mmWave and THz Technology Opportunities

A comprehensive report on projected uses of mmWave and THz technologies can be found in: “Emerging Technologies and their expected impact on Non-Federal Spectrum Demand”, OSTP, May 2019.

[https://www.whitehouse.gov/wp-content/uploads/2019/05/Emerging-Technologies-and-Impact-on-Non-Federal-Spectrum-Demand-Report-May-2019.pdf]

Another source, to understand where the demand comes from, are the CISCO VNI Reports (“Visual Networking Index” and accompanying White Papers)

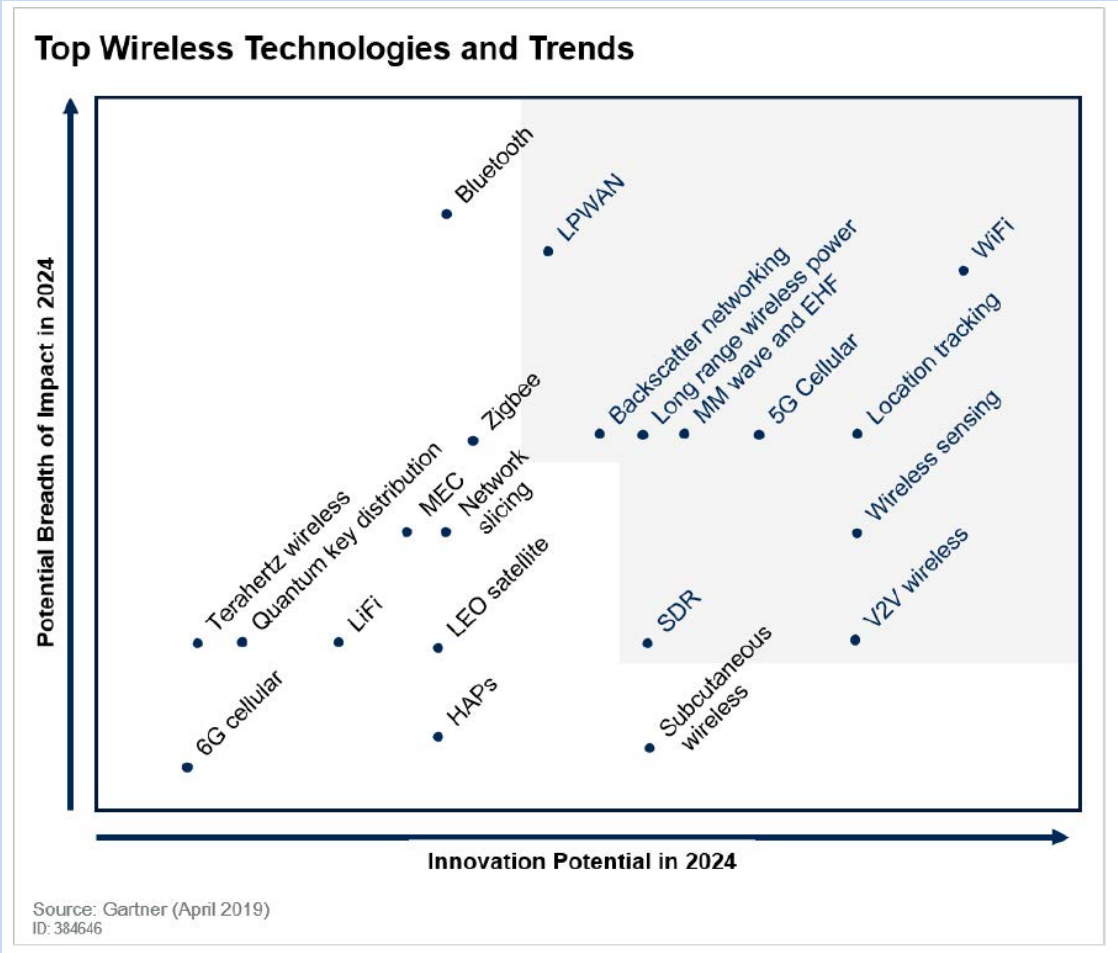
[https://www.cisco.com/c/en/us/solutions/service-provider/visual-networking-index-vni/index.html]

A bit about: mmWave and THz Technology Opportunities

A few of the drivers:

- Annual Growth in network traffic: overall > 20% with mobile > 40% as a multi-year trend.
- Demand for higher bandwidth – Think of the history from 110baud for the early connectivity to today's average above 25Mb/sec with near term expectations exceeding 1Gb/sec.
- The value and desirability of Nomadic and Mobile Communications
- Basic shifts in network architectures to satisfy access to other technologies that are fueling IoT growth: computing, storage, ……
- Dependence of IoT on common infrastructure – reliable, reachable, and affordable.
- Looking at promising IoT use cases a need for Area vs Population Coverage
- With IoT thriving on data (sensors) an unprecedented demand for information where mmWave and THz devices are competing with other technologies but have unique characteristics where they may be the only way of getting the job done.

A bit about: mmWave and THz Technology Opportunities



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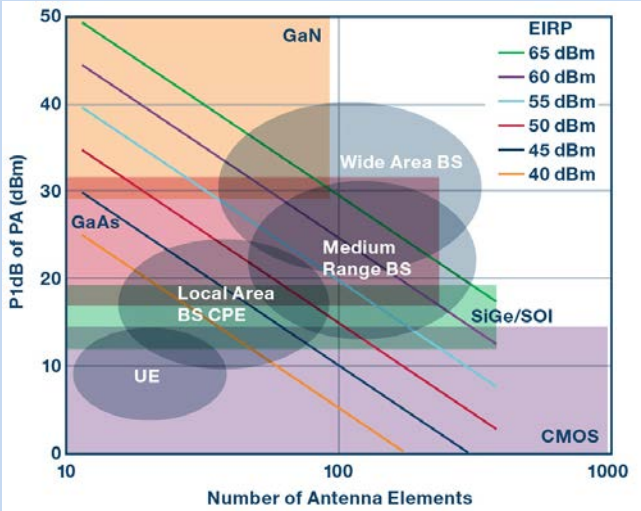
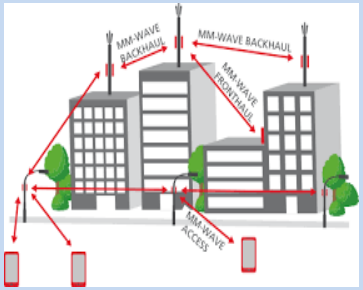
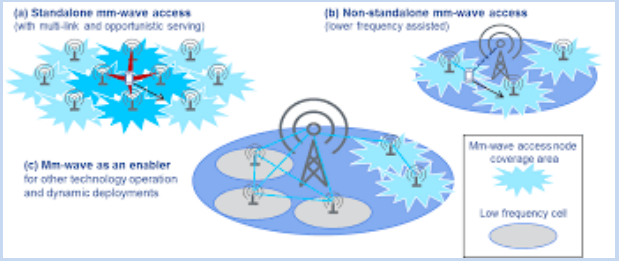
A bit about: mmWave and THz Technology Opportunities

For Communications:

Standard	Band Name	Frequency (GHz)
ITU	EHF	30-300
IEEE	Ka	27-40
	V	40-75
	W	75-100
	mm	110-300
Waveguide Bands	Q	33-50
	U	40-60
	V	50-75
	E	60-90
	W	75-110
	F	90-170
	D	110-170
	G	140-220
	Y	170-500







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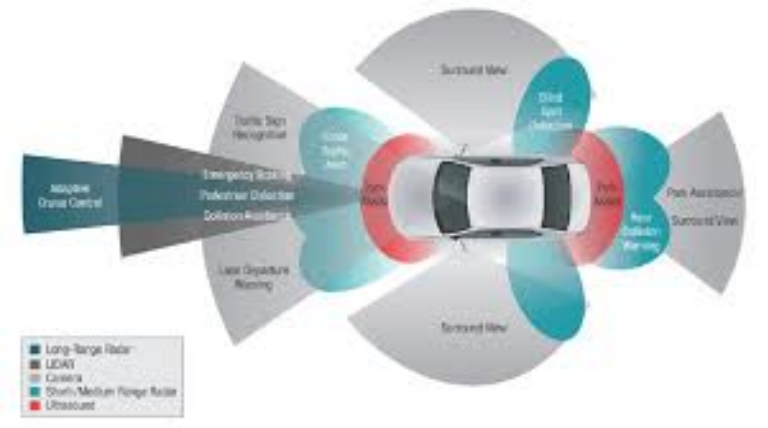
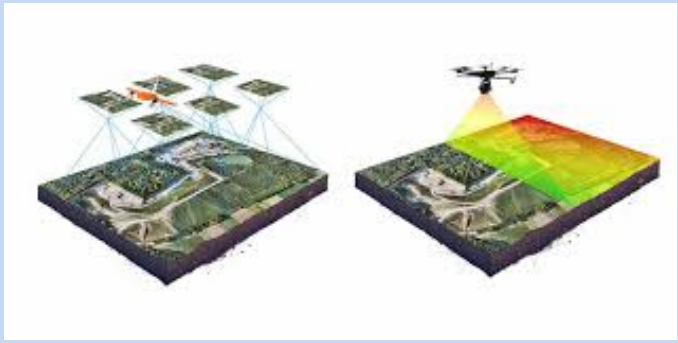
A bit about: mmWave and THz Technology Opportunities

For Sensing:





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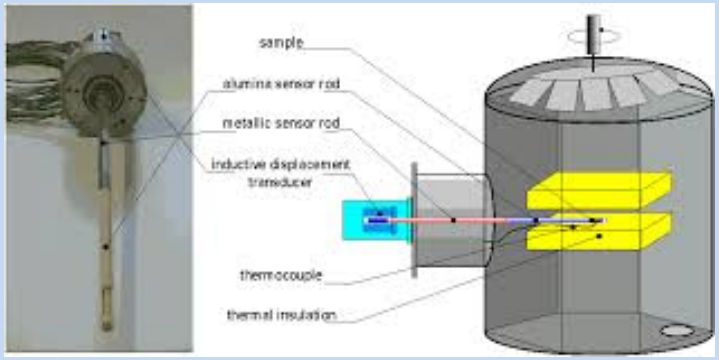

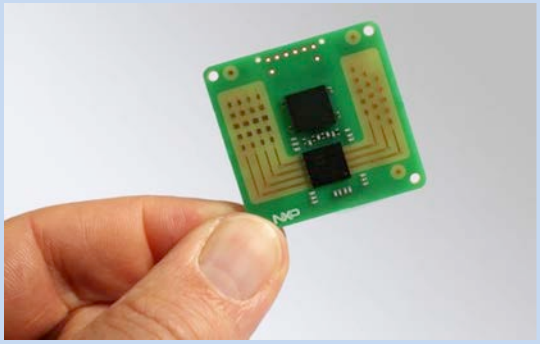

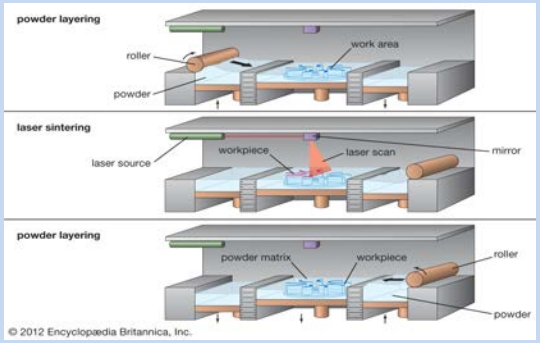

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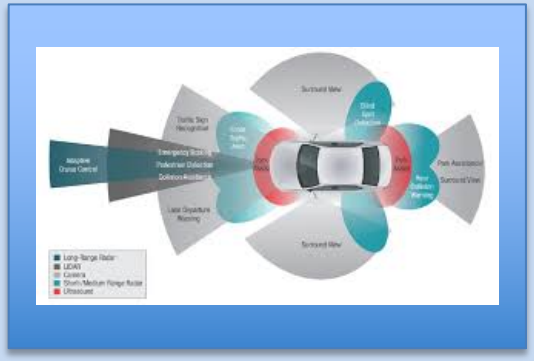
Thank you!



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