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Can a Smarter Grid Slow Down Climate Change While Accelerating Energy Independence?

Symposium ID 4120, Organized by Dr. Hassan Farhangi, PI NSMG-Net

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Agenda

Speaker #1:	Dr. John Macdonald – Day4 Energy (Founder and Chairman)
Title:	Future of energy systems and unsustainability of status quo
Speaker # 2:	Mr. Kip Morison – BC Hydro (Chief Technical Officer)
Title:	Utility perspectives on issues confronting the energy industry
Speaker # 3:	Dr. Hassan Farhangi – BC Institute of Technology (Director)
Title:	Smart Grid and its role in achieving energy independence
Speaker # 4:	Dr. Reza Iravani – University of Toronto (Professor)
Title:	Managing demand through a smarter distribution system
Speaker # 5:	Dr. Geza Joos – McGill University (Professor)
Title:	Expanding production capacity thru renewable sources of energy
Speaker # 6:	Dr. David G Michelson – University of British Columbia (Professor)
Title:	Role of ICT in transforming the existing grid into smart grid
Discussant:	Dr. Chris Marnay - Lawrence Berkley National Lab (Staff Scientist)

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The Role of ICT in Transforming the Existing Grid into a Smart Grid

Prof. David G. Michelson
University of British Columbia

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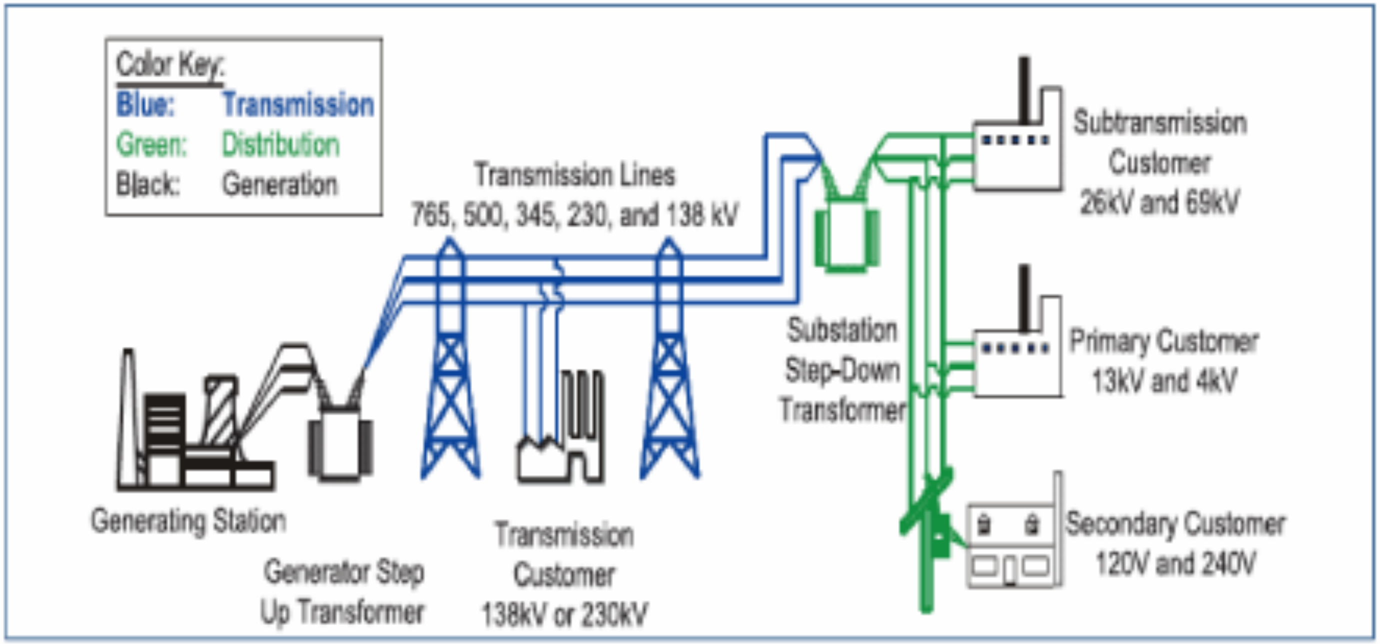
Agenda

1. ICT and the Existing Power Grid
2. ICT and Grid Modernization
3. The Challenges for ICT
4. Design Goals for Smart Grid ICT
5. The Case for Unified & Heterogeneous ICT Infrastructure
6. Conclusions

1. ICT and the Existing Power Grid



- The Bulk Power System is well served by existing microwave, fibre and SONET/SDH-based communications networks
- The Distribution Grid is served by very limited SCADA and supervisory control
- Grid modernization seeks to overcome this limitation

ICT and the Bulk Power System

- Since the 1960's, virtually all electrical power systems in southern Canada and the continental United States have been interconnected.
- However, the Northeast Blackout of 9 Nov 1965 raised serious concerns regarding standards and procedures for operating the bulk power system.
- The North American Electricity Reliability Council was formed in 1968 to develop, monitor and enforce compliance with operating standards.
- Power utilities have considerable experience in deploying the microwave, fibre and SONET/SDH-based networks that play a key role in assuring the reliability of the bulk power system.

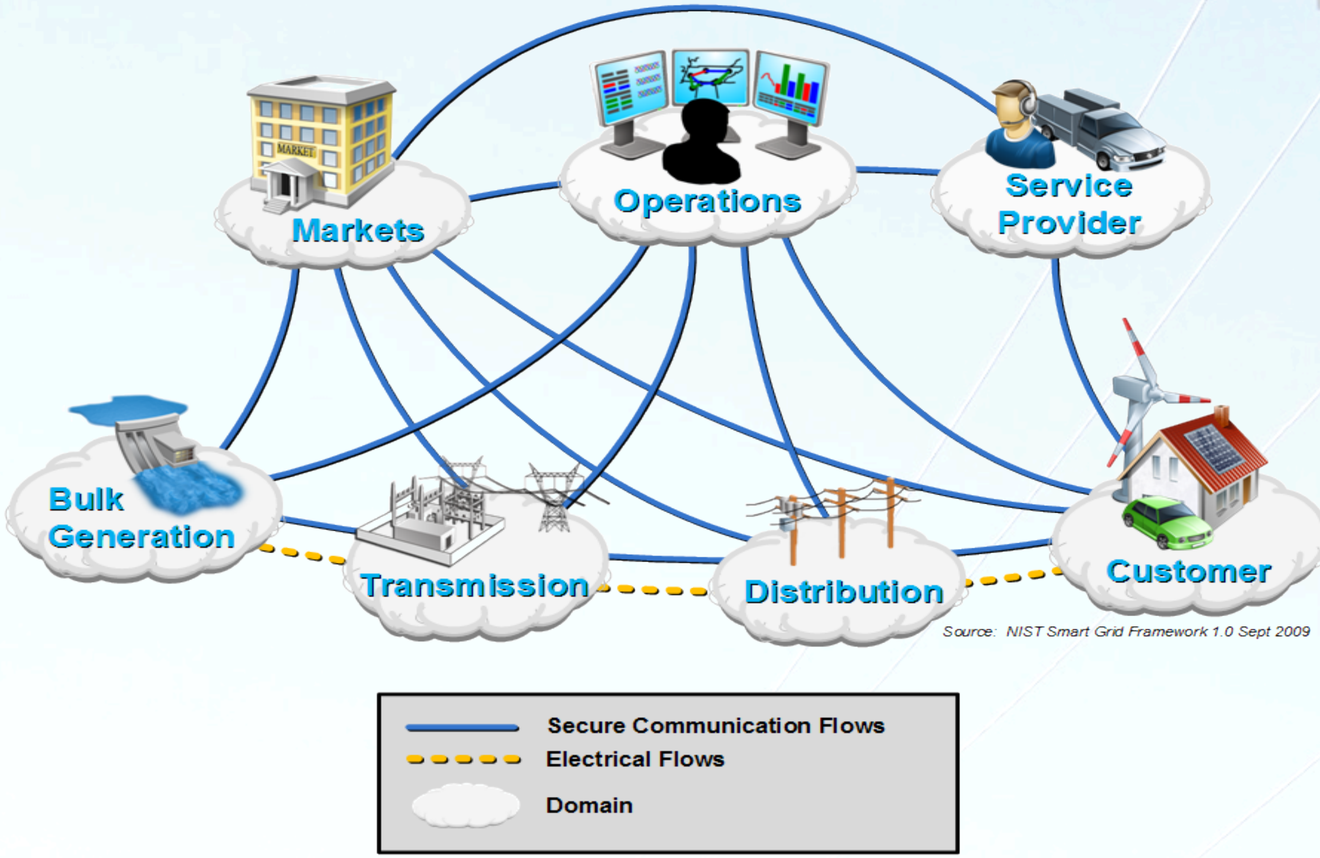
ICT and the Distribution Grid

- The distribution grid is the portion of the electrical power system that lies between substations and residential, commercial or industrial customers.
- Because, there are no issues or concerns regarding interoperability with other utilities, each utility operates their own distribution grid as they see fit.
- The number of utility assets and customer locations in the distribution grid is immense compared to the number of nodes in the bulk power system.
- As a result, it is not practical to simply extend the bulk power system's communications network to the distribution grid.

2. ICT and Grid Modernization

- Grid modernization involves development and implementation of:
  - new power system architectures that:
    1) make effective use of distributed generation
    2) reduce the need for massive investments in bulk generation capacity, and
    3) enhance power system reliability
  - new methods and applications for monitoring, operating and controlling power systems based upon the new architectures
  - new methods and applications for interacting with consumers
- **ICT will be a key enabler of such initiatives.**

NIST Conceptual Model



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ICT Infrastructure for Smart Grid

- Until recently, the technology required to extend command and control capability into the distribution grid at the required price-performance point was simply not available.
- Recent developments in wireless, power line and fibre optic communications suggest that it should now be possible to realize ICT infrastructure that meets this requirement.
- The requirements of the modernized grid are sufficiently different from those of consumer and corporate IT that substantial effort will be required to develop the required technology and verify its performance.

Smart Meters & Distribution Automation

Smart Meters

- Smart metering focuses on connecting to customer premises in order to: 1) monitor electrical power consumption and 2) interact with the costumer and possibly customer loads and other assets.

Distribution Automation

- Distribution automation focuses on monitoring and controlling power utility assets within the distribution grid, e.g., switches, reclosers, voltage regulators and transformers.

Security concerns require that Smart Meter and Distribution Automation networks be isolated.

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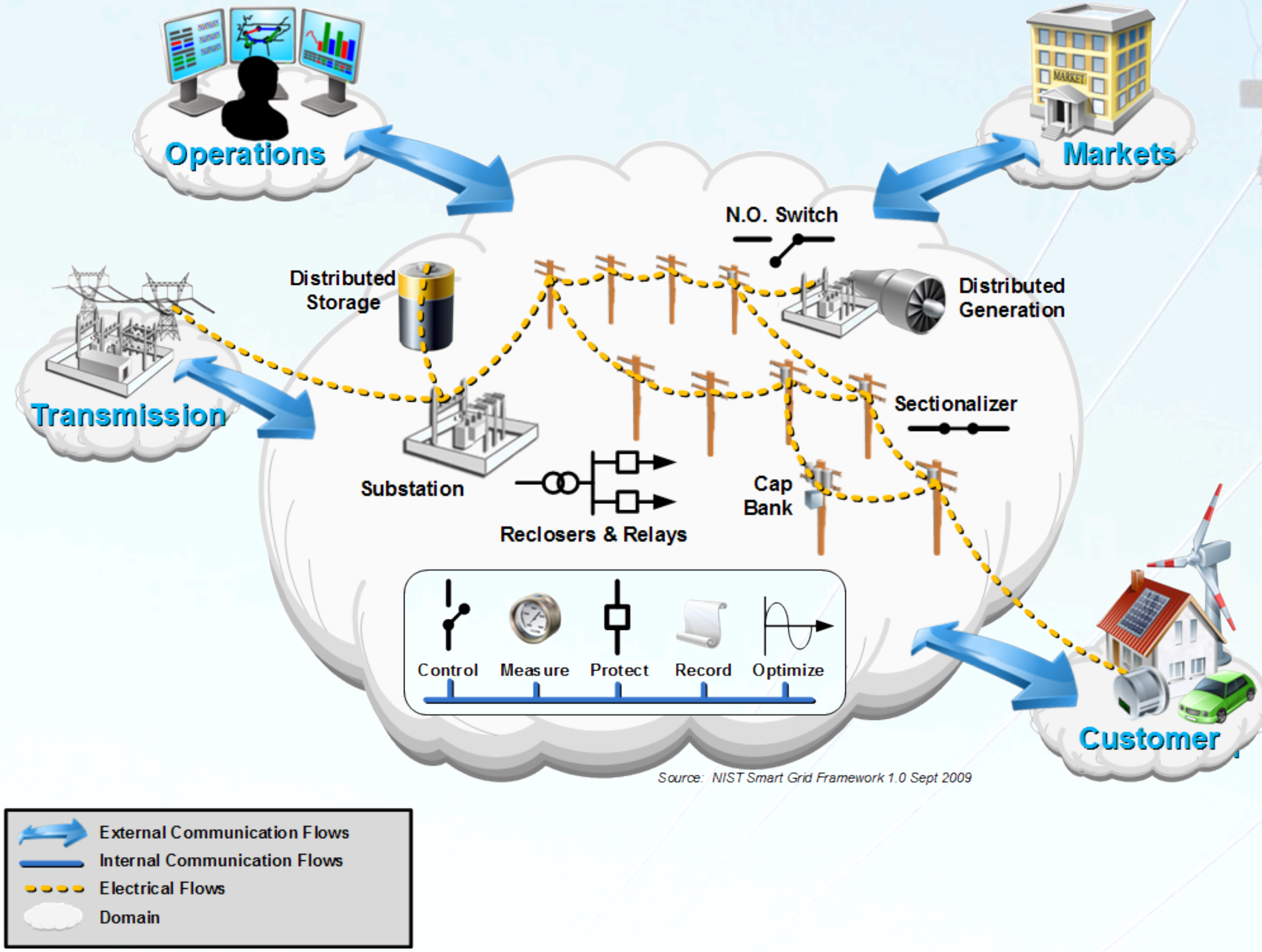
NIST Conceptual Model

Distribution



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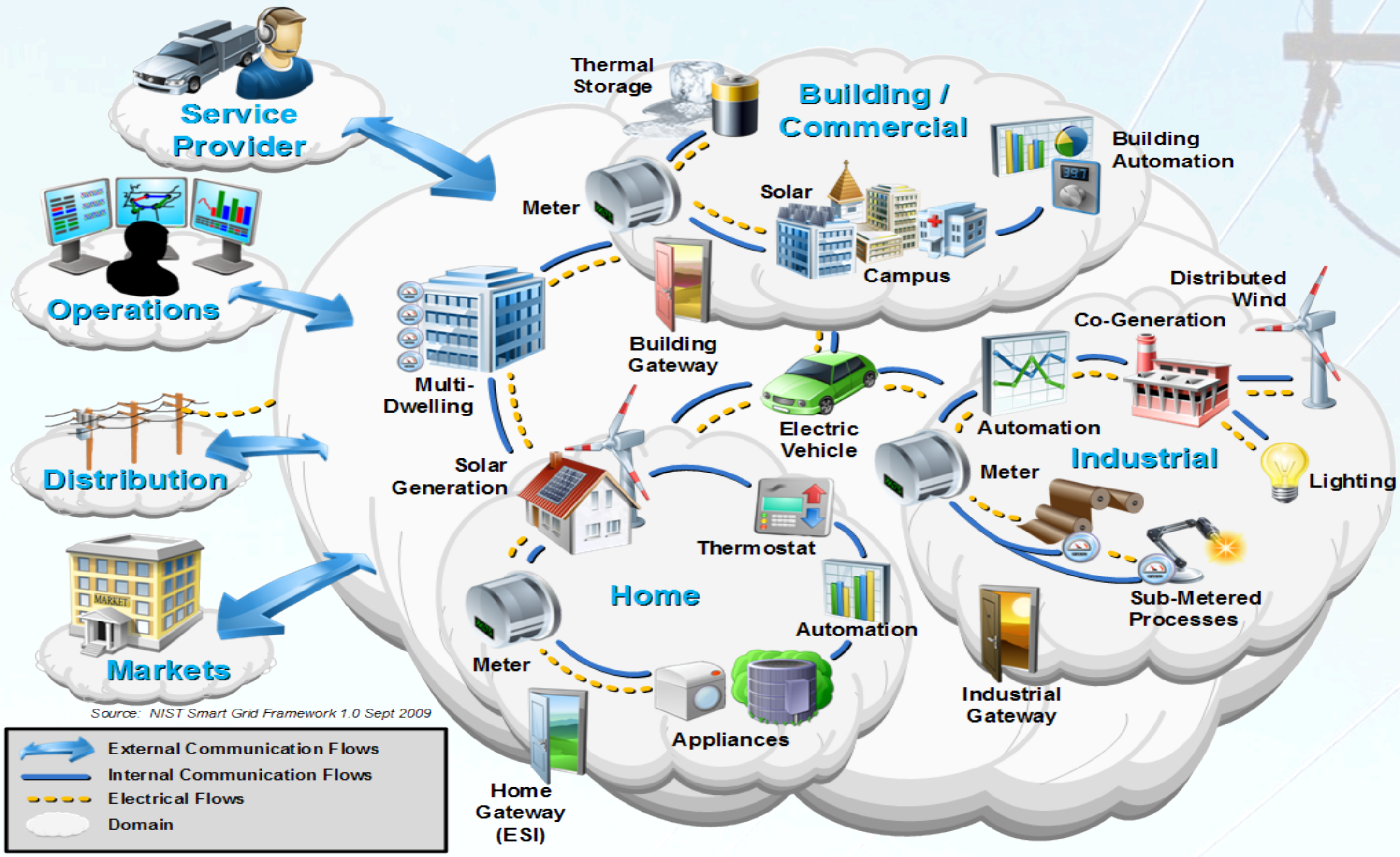
NIST Conceptual Model

Customer



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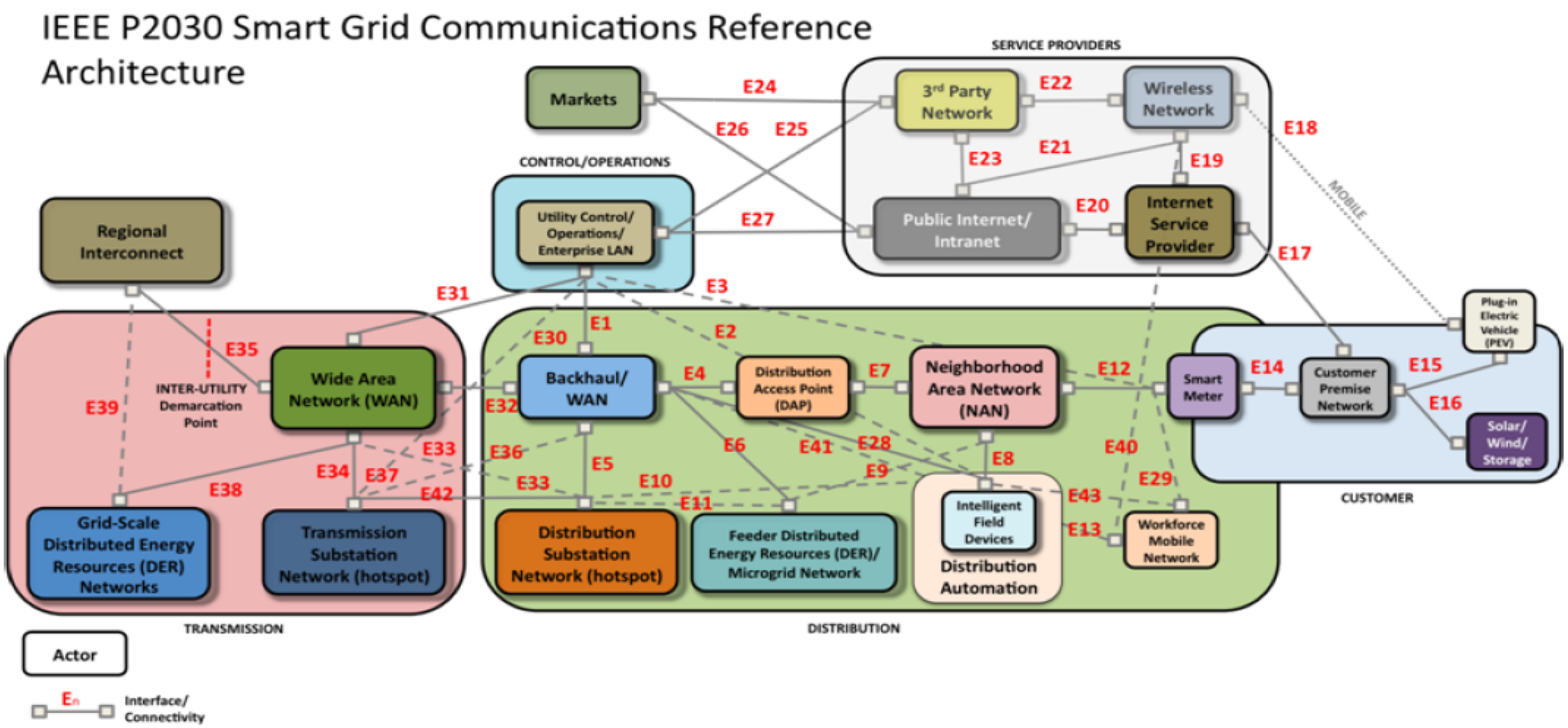
3. The Challenges for Smart Grid ICT

Those developing ICT infrastructure for Smart Grid must:

- satisfy a far more conservative business model than those followed by common carriers engaged in deployment of networks of similar size and scale,
- achieve network performance goals that are different from those of conventional ICT networks,
- achieve levels of reliability similar to those engaged in automation of industrial plants but over networks of much greater physical size and scale, and
- account for significant evolution of the requirements for performance and capabilities as power system architecture evolves during the next twenty years.

- be prepared to account for the complexity inherent in a system that has evolved and developed over decades

P2030 Smart Grid Comms Reference Architecture



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Focus on Smart Grid Applications

- Grid modernization (or Smart Grid) is a diverse set of improvements and innovations that will be implemented over the next two decades.
- In a presentation to the Smart Grid Canada 2011 conference, Julius Pataky identified four phases that are likely to occur over the next twenty years; others have proposed similar road maps.
- As ICT infrastructure designers, our goal is not simply to connect devices to a network; it is to connect applications to devices.
- Understanding Smart Grid applications is the key to understanding the needs and performance goals that Smart Grid ICT Infrastructure must meet.

	Phase1	Phase2	Phase3	Phase4
Policy Drivers	•Energy Efficiency •Smart Meter Regulation •Conservation Rates •Reliability •NIST Standards	•Carbon Tax Regulation •Climate Change Policy •Feed-in-Tariff •Low Carbon Fuel Regulation •Critical Infrastructure Protection •Renewable Portfolio Standards	• Cost Recovery Models • Market Regulation • Tariff Design • Research and Development Policy • Data Privacy Policy • Cyber Security Policy	• Building Efficiency Policies • Transmission Policy • Liberalized Markets Regulation
Applications	• **Smart Metering** • **Volt Var Optimization** • **Distribution Automation (FLISR)** • **Distribution Management** • **Substation Automation** • **Workforce Automation** • **Energy Diversion Analytics**	• **EV Smart Charging** • **Distributed Generation Controls** • **Synchrophasor applications** • **Transmission Optimization Applications** • **Model Based Asset Management** • **Predictive Equipment Maintenance**	• **Small Scale Storage Applications** • **Ancillary Services** • **Demand Response** • **3rd Party Energy Aggregation Services** • **Electric Vehicle to Home**	• **Large scale storage applications** • **Transmission super-highway** • **Smart Neighborhoods** • **Microgrid** • **Electric Vehicle to Grid**
Technology Outcomes	• **Smart Metering Infrastructure** • **Transformer Tap Changers** • **Open Loop System Topology** • **Automated Distribution Devices** • **Distribution Management System** • **Substation Automation Systems** • **Distribution Automation Systems** • **Information Comms. Technology** • **Mobile Field Client Systems**	• **Smart Charging Control Systems** • **Measurement Canada Sub-Metering** • **Distributed Generation Control Systems** • **Process Bus** • **WASA Control Applications** • **Dynamic Rating Technology** • **Simulation Tools** • **Interoperable Standards**	• **Community Energy Storage** • **Net Zero Homes** • **Advanced Power Electronics** • **Remote Load Control Systems** • **Customer Side Systems** • **Grid Friendly Appliances** • **Dynamic Pricing** • **Interoperable Standards**	• **Grid Scale Storage Systems** • **DC Based Buildings** • **Large renewable energy sources** • **Superconductors** • **HVDC Transmission Lines** • **New Energy Markets** • **Net Zero Communities** • **Interoperable Standards**
Benefits	•Energy Conservation •Lower Electricity Rates •Reliability Improvements •Workforce Efficiency •System Efficiency and Optimization •Revenue Protection •Safety Improvements	• Fuel Switching and Emissions Reduction • Renewable Energy Integration • Grid Stability and Control • Transmission Congestion Reduction • Reduced System Losses • Energy Security • Improved Asset Utilization	• Congestion Management • T&D Avoided Capital Costs • Reliability Improvements • Reduced Peak Electricity Demand	•Premium Reliability •Increased Transmission Capacity •Virtual Power Plant Enablement •Large scale renewables integration

20 Year Timeline

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4. Design Goals for Smart Grid ICT

- Each item on the hierarchy must be satisfied before successive items add value.

Security

Capacity

Throughput

Latency

Reliability

Connectivity (Coverage)

- Not a list of priorities!
- Not a design sequence!

- A different sequence would apply to Common Carrier or Corporate ICT infrastructure!

Consequences

- Existing ICT standards and equipment are designed to meet a different design goal hierarchy than Smart Grid ICT requires
- Modifications must often be made to existing ICT standards and equipment before they will satisfy Smart Grid requirements.
- Identifying the requirements and gaining consensus regarding the changes represents a major challenge.

Challenge 1 - Coverage and Connectivity

- Wireless, fibre, power line and common carrier (cellular, satellite) communications are all candidates for interconnecting Smart Grid devices.
- Achieving the desired coverage and connectivity is often taken for granted but is proving to be challenging and expensive for power utilities.
- Customer and Distribution assets are often located in difficult locations, e.g., due to long distance, excessive path loss, lack of right-of-way, interference.
- Accurate characterization of the environment and corresponding impairments helps designers make good decisions and avoid unpleasant surprises.

Challenge 2 – Reliability and Latency

- Reliability and latency are not usually priorities in consumer oriented communications services.
- By contrast, they are often significant priorities in Smart Grid ICT networks.
- Requirements are most easily met but at great expense using dedicated links; far more difficult to achieve in multiple access networks.
- Smart Grid ICT researchers are rethinking Medium Access Control and Network Routing protocols in light of these requirements.

Challenge 3 – Throughput and Capacity

- Compared to conventional networks, the throughput requirements per device in Smart Grid networks are miniscule.
- However, the sheer number of devices attached to the network raises important capacity issues.
- In many cases, designers will negate the advantages associated with low throughput per device by increasing the physical extent of the branch or cell compared to conventional networks.

Challenge 4 - Security

- Neither the integrity of the grid nor the privacy of customers must be compromised.
- Increased connectivity provides additional opportunities for criminals to gain unauthorized access and do damage.
- Conventional ICT interpretations of security are insufficient due to the presence of numerous control loops and legacy systems.
- Account must be taken of both: 1) power system needs and conventions and 2) lessons learned from industrial plant operation.

5. The Case for Unified & Heterogeneous Communications Infrastructure

To what extent should Smart Meters and Distribution Automation share ICT infrastructure?

"We've cautioned before that we may be building the [smart] grid @$$ backwards"

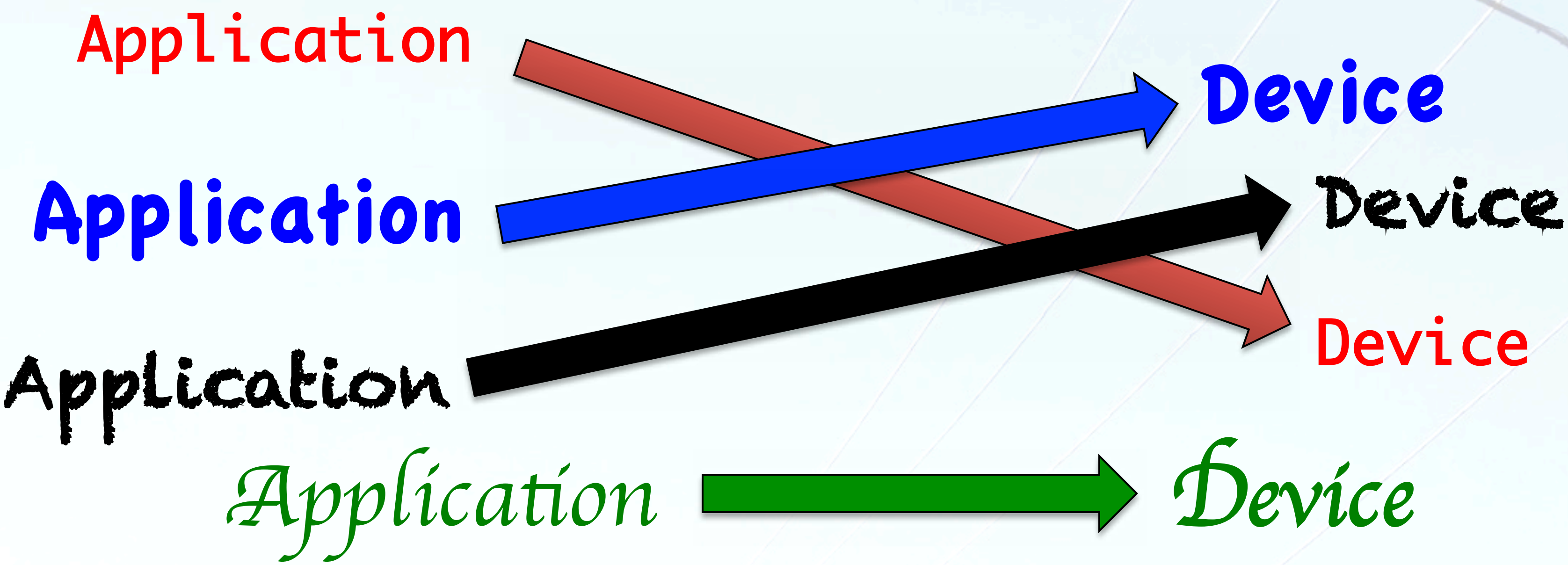
– SmartGridNews, 3 Jan 2011

"[They] could spend a fantastic amount of money building a system that is obsolete as soon as it is built."

- Eric Dresselhuys, Silver Spring Networks

Dedicated Communications Infrastructure

- Dedicated infrastructure offers the best performance but at great expense.



Unified & Heterogeneous Communications Infrastructure

- Sharing infrastructure offers economies of scales but risks performance mismatch.

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Success or Failure in Network Design: The Issues

How will we know if we have succeeded or failed?

- Did we meet our cost goals?
- Did we meet our performance goals?
- Do applications perform as expected?
- Can we improve or grow network performance or capacity at a reasonable cost in the future ?

Success or Failure in Network Design: Margin for the Future

- As grid modernization evolves, effective unified communications infrastructure can be seamlessly upgraded to meet user requirements.
- Overly clever designs today can lower implementation costs but may require costly large-scale replacement of infrastructure in the years to come.

Success or Failure in Network Design: Misunderstandings by Developers

- Application users and developers may focus on the network interface without accounting for the inner workings of the network.
- As a result, legacy applications may exhibit unexpected or undesirable performance.
- Alternatively, developers may make poor decisions when developing or implementing applications or protocols and achieve unexpected or undesirable performance.

6. Conclusions

Unified ICT infrastructure:

- connects applications to devices.
- is the lynchpin that will hold the Smart Grid together and make it affordable
- must satisfy six fundamental performance criteria while loaded by varying levels of heterogeneous traffic and applications:
  - coverage/connectivity,
  - reliability,
  - latency,
  - throughput,
  - capacity,
  - security.

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Conclusion - 2

- Smart Grid ICT infrastructure must meet different (and perhaps more demanding) price-performance goals than common carrier, corporate or residential ICT infrastructure.
- Identifying these performance goals can be as difficult as designing the unified ICT infrastructure that meets them.
- Existing technologies such as TCP/IP, WiMAX and ZigBee hold great promise for Smart Grid ICT infrastructure but must often be modified or extended in order to meet these goals.

Conclusion - 3

- Verifying that the performance goals have been met, especially under extreme conditions, will likely be very difficult.
- Future needs and goals must be anticipated and a path for growth and evolution identified in order to control costs.
- Application developers must appreciate both:
  – the impact of their applications on unified ICT network performance, and,
  – the impact of the unified ICT network on their application's performance.

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