Implementing the Smart Grid: Lessons Learned from the Internet

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U.S. Today

- Over 3,000 utilities with assets valued at over $ 800 billion
- 10,000 power plants
- Most of the system is 30-50 years old
- The nation’s “electric bill” is about $247 billion annually
- 40% of total U.S. energy consumption is used to produce electricity

Power outages cost the U.S. economy from $25 billion to $180 billion annually

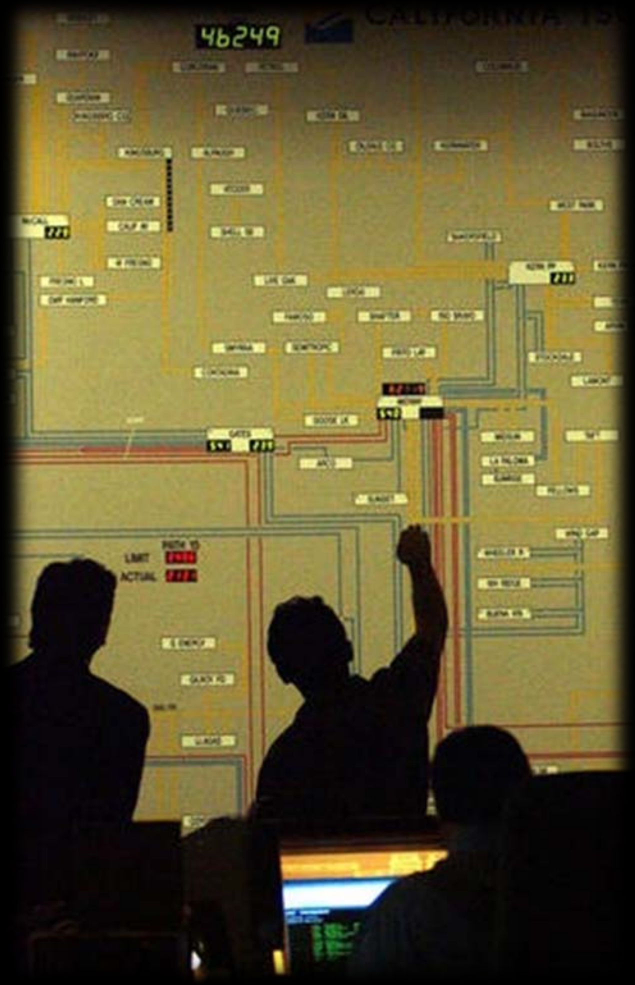
U.S. Stimulus: A Down Payment

- $4.5 billion for smart grid
- $3.4 billion in matching grants awarded to 100 utilities across U.S.
- $8.1 billion total investment
- Many see as “Down Payment” on future investment

As engineers, what can we do to help maximize these public-private investments?

Smart Grid: A Common Definition

A secure, two-way data communications system that will provide electric utilities with real-time visibility of the electricity used by customers, integrate renewable energy and balance supply and demand, leading to a reduction in waste and increased efficiencies



Lesson 1: Supportive Government is Essential

- Research: Birth of the Internet was aided by funding from Department of Defense in 1969
- Public/Private Partnerships: ARPAnet was a partnership between government and academia
- Policies Encouraging Innovation & Competition:
  - Anti-Trust: 1968 FCC ruling allowed non-ATT products to connect to ATT network
  - Access to Markets: 1991 NSF lifted all restrictions on commercial use of the network, giving birth to the World Wide Web
    In one year, Internet hosts go from 300,000 to over 1 million
  - Open-Access Transmission: 1996 FERC issued Order 888 and Order 889, requiring all jurisdictional utilities (within U.S.) to file an Open-Access Transmission Tariff (OATT)

Lesson 2: Ability to Scale is Critical

- Regardless of the domain that an application, protocol, or technology is designed for, it must be able to cross arbitrary distances and be used by a vast number of systems
- Standards provide a common set of network protocols that can run end-to-end over a variety of underlying physical and link layer technologies
- Open Standards - owned by non-profit organizations and networking industry groups - enable interoperability, growth, adoption and innovation

Cisco's Involvement & Leadership:
Evolution of Global Communications

- Involved in the development of every routing protocol and every major Internet feature below the application layer since 1989.
- Involved in 80+ SDOs and forums, including the IETF, IEEE, and ITU-T, and has significantly contributed to Internet standardization especially in the IETF.
- Supported two IETF chairs over a period of nine years, IAB and IESG members, and about 10% of IETF working group chairs.
- Dedicated to making the Internet Architecture work well on all implementations, for both partners and competitors

Lesson 3: Think Security, Day One

- The original Internet grew rapidly in the absence of security. In smart grid, we have the opportunity to "bake-in" security upfront, and not bolt-on after the fact.
- Address the most relevant security concerns first, rather than applying whatever is around. Priorities:
  - Attacks that prevent the Smart Grid from accessing resources it depends on
  - Attacks that find and trigger inherent bugs
- Retrofitting security is nearly impossible and current IP specifications mandate security considerations

Lesson 4: Simplicity Over Perfection

"The *Simplicity Principle*… states that complexity is the primary mechanism which impedes efficient scaling, and as a result is the primary driver of increases in both capital expenditures (CAPEX) and operational expenditures (OPEX)."

- The implication for carrier IP networks then, is that to be successful we must drive our architectures and designs toward the simplest possible solutions.
- The IP protocol is not optimized for any application, yet it can serve all applications
  - It provides the right trade-offs among optimization, flexibility, and cost

Meyer and Bush, quoting Mike O'Dell

RFC 3439 http://www.ietf.org/rfc/rfc3439.txt

Lesson 5: Evolutionary Flexibility

- When the Internet was first conceived, current link layers like Ethernet and WiFi didn't exist

  Common communication used Async; HDLC/SDLC were developed later. The Internet used BBN 1822, a proprietary protocol

- Separation of the upper layers from the link layer enabled the Internet to evolve as new technologies were developed without having to rethink applications or transports:

  Satellite communications, X.25, Ethernet, Token Ring, Frame Relay, ATM, SONET/SDH, 802.11, 802.15.4, 802.16, MPLS, and others

- The same separation will enable the evolution of the Smart Grid; tying applications to link layers inhibits both technical and business innovation

Lesson 6: Allow for Innovation at the Edge

- Open communication and programmable endpoints lead to serendipity
  - Unexpected, new applications/systems/"mashups" get created by clever entrepreneurs
- Innovation creates demand in the network, much more than the other way around
  - That demand leads to evolution and innovation in the network to meet it, and these further enable innovation at the edge
- Allow for intelligence at the edges, don't assume you have to solve all major problems in the network itself
  - A small tweak in intelligence at the edge can save a lot of gymnastics in the network, e.g. around routing and connectivity

Lesson 7: More Bandwidth

- The speed of innovation increases with time
- Future applications will require additional bandwidth
- Networks which are designed for today's need will become absolute quickly
- Allow margins for future growth

The U.S. has over 140 million homes
If each home has an average of 10 end points and those are connected to the grid,
over 1,400,000,000 sensors - transmitting data - would be added to the existing grid infrastructure

Overall Lessons from the Internet

Things We Did Well

- The service is connectivity
- Designed for scale beyond imagination
- Simplicity and Standards are the watchwords
- Elegance, re-usability, and flexibility are keys to scaling, evolution, & innovation

Things We Wish Had Been Done Better

- Designed for secure channels and secure objects
- Designed for manageability

Key Takeaway: Internet Protocol (IP)

- Complete network architecture with all aspects of performance, scalability, security, manageability, extensibility and interoperability
- Enhanced capabilities to serve an ever-increasing scope of requirements.
- With an enormous amount of investment and multitude of companies globally that rely on it, IP is a communications platform that cannot be duplicated by any niche protocol

IP can and should serve as the unifying network architecture that will accelerate deployment of smart grid, and help to quantify the economic and environmental benefits of smart grid over time

CISCO

Smart Grid Security:
Don’t Talk to Strangers

- Applications have different views of their clients and peers:
  - May simply respond to requests – DNS, WWW
  - May have some peers they trust more than others – SMTP
  - May only trust certain peers – routing
- In general, authenticate and verify authorization of peers
  - Expend as little resources as possible rejecting peers
  - IPsec, TLS examples of tools
- Largely about *securing a channel* for information exchange
  - Limit it to trusted parties when possible