The Evolution of the Internet Community and the "Yet-to-evolve" Smart Grid Community:

Parallels and Lessons-to-be-learned

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The Shared Smart Grid Vision

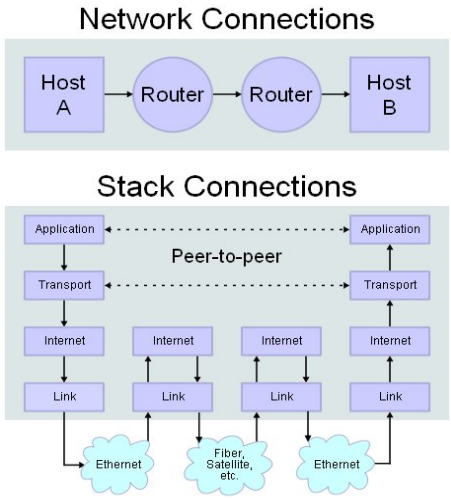
- "Community" of co-operating energy-related devices deployed as part of our national power grid to enhance system flexibility, security, and robustness.
  - Devices capable of independent action ("smart")
  - Interconnected and communicating with other devices ("grid")
- The Smart Grid will be a transformative technology that will, eventually touch effect every part of our existing power grid - including every home.
- Unlike other such transformations (modern digital computers, optical cables), the success of the Smart Grid will not depend on a single new technology – but, rather on its ***system architecture***.

A *Very* Brief History of the Internet

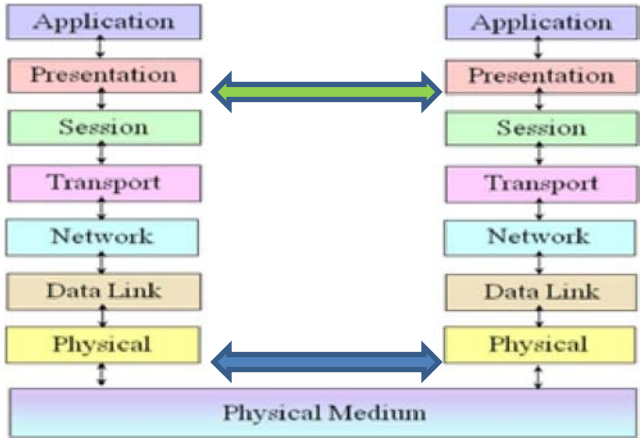
- ARPA-funded project (1962) to create resilient computer networks.
  - Centralized administration viewed as the achilles heel of existing designs.
  - "How do you manage a network of 100's of computers in a disaster or war scenario?"
  - IP protocols turned out to be reasonably lightweight and *VERY* scalable.
- Lots of competing designs during 80's and early 90's.
  - IPX (Netware), X.25, etc.
  - In the network world, this intensively competitive period was known as the "great protocol wars".

Internet History(contd).

- "IP" protocols ultimately prevailed.
  - Based on providing "just enough" functionality – never too much.
  - Architecture could be deployed on a large scale.
  - Minimal centralized administrative overhead.
  - Promoted a "layered" architecture that kept internal implementation details compartmentalized.



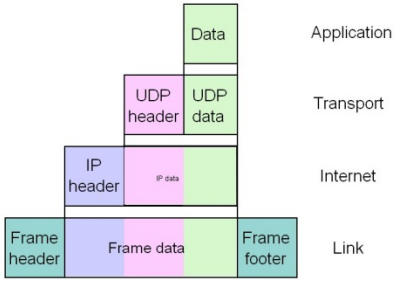
Internet 4-Layer Stack



OSI 7-Layer Stack

What does "Internet" really refer to?

- 1. The IP family of data communications protocols.
  - Describes mechanics of packaging data into frames and routing it through the network.



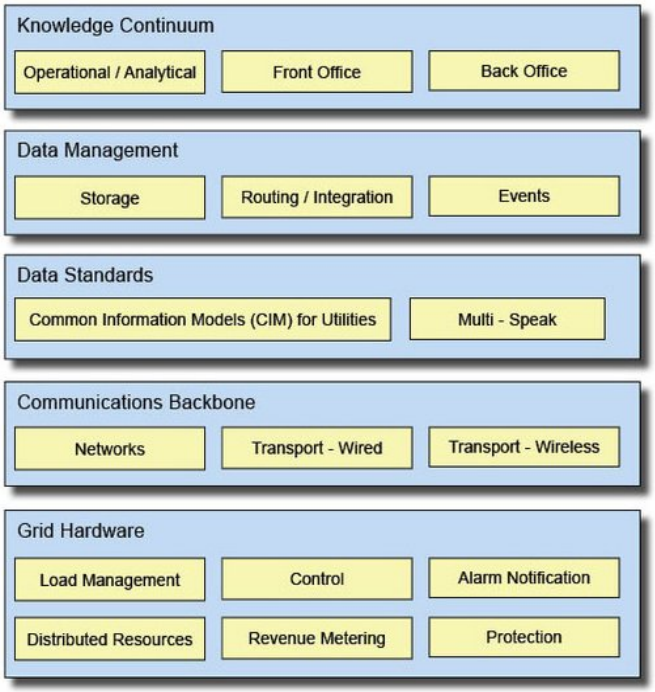
- OR -

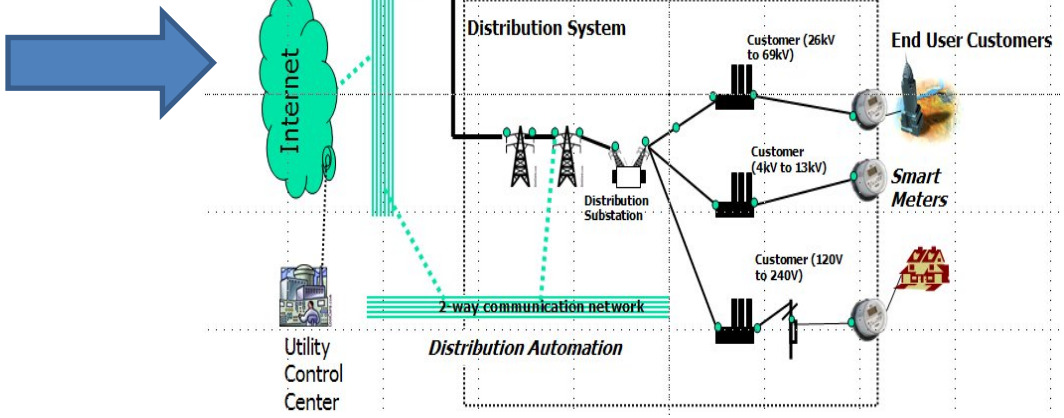
- 2. The modern public network that millions of people experience and interact with every day.
  - Simple services: time, email, file transfer
  - Interactive services: www, browsing, searches
  - Enabling services: eCommerce, video delivery
  - Transformative services: uTube, FaceBook, etc.

- Internet users have a highly developed set of expectations

The Smart Grid isn't the Internet

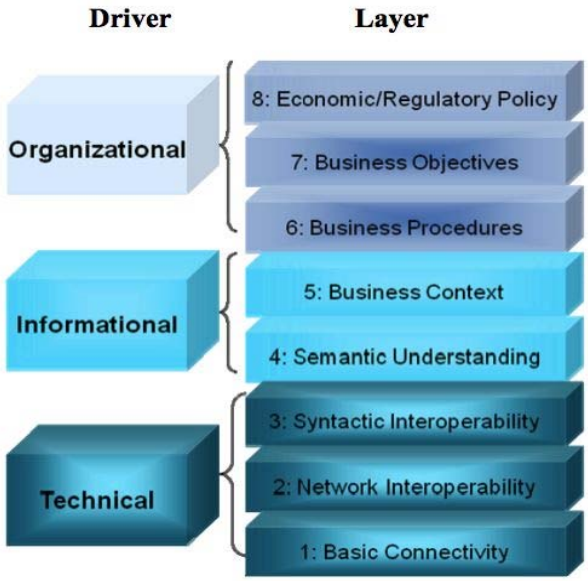
- Power grids have some constraints that IP protocols do not address –critical latencies, real time response.
- Specialized networks have a well-deserved place in the grid system architecture- Private networks, optimized protocols (DNP3, IEC 61850…).





Grid Wise Framework/Architecture Stack

- GWAC stack codifies interactions across a wide range of grid activities.
  - viz. Internet analogy, it covers both network and Internet application area.
  - While it covers the customer interface it does not fully embrace all the implications of the “Smart House”.



GWAC Framework

- While similar to Internet model, there are differences.
  - Governance (open vs. closed).
  - Dynamic, innovative pace of Internet development vs. stability requirements for grid operations and business needs.
  - Predictable “culture clash”.

With the Customer comes the Internet

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Storage
Data Standard
Common Infor
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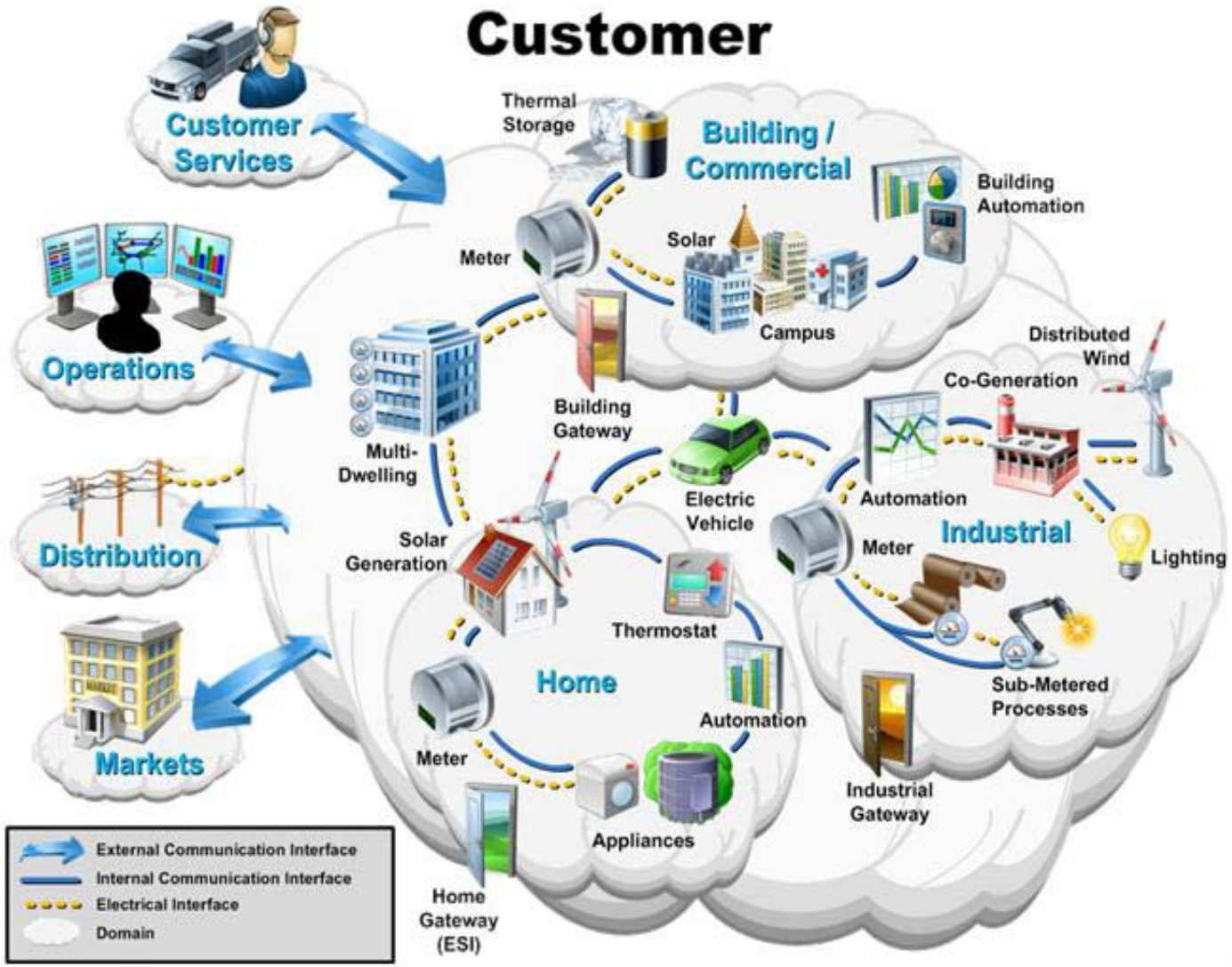
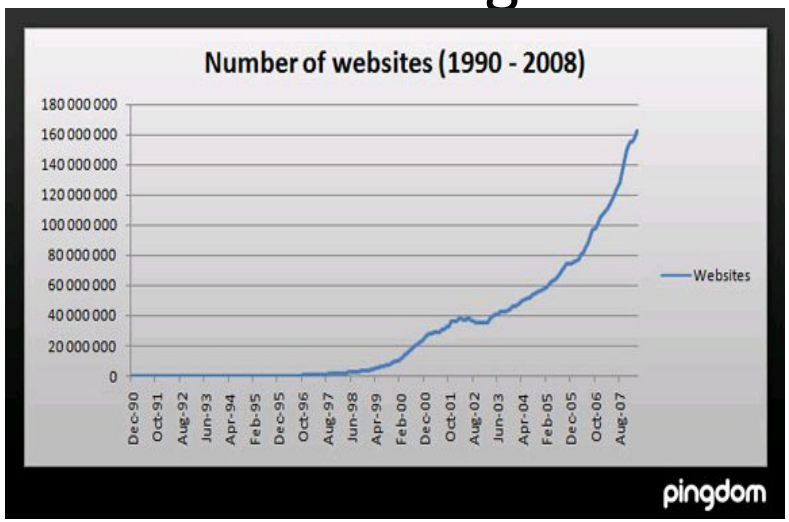
Network
Grid Hardware
Load Manage
Distributed Res



Lessons from the Internet

- Internet is huge, "built" environment – has begun to express "community" values.
  - Little centralized governance - but growing shared enforcement.
- History of network innovation and (re)engineering.



  - Successful and not-so-successful search engines (Google, AltaVista, Excite@home.).
  - Lessons for the Smart Grid:
    - Finding things on the Internet
    - Talking to things on the Internet
    - Home automation and the Internet (and the Smart Grid)
    - "Smart Users"

Finding "things" on the Internet

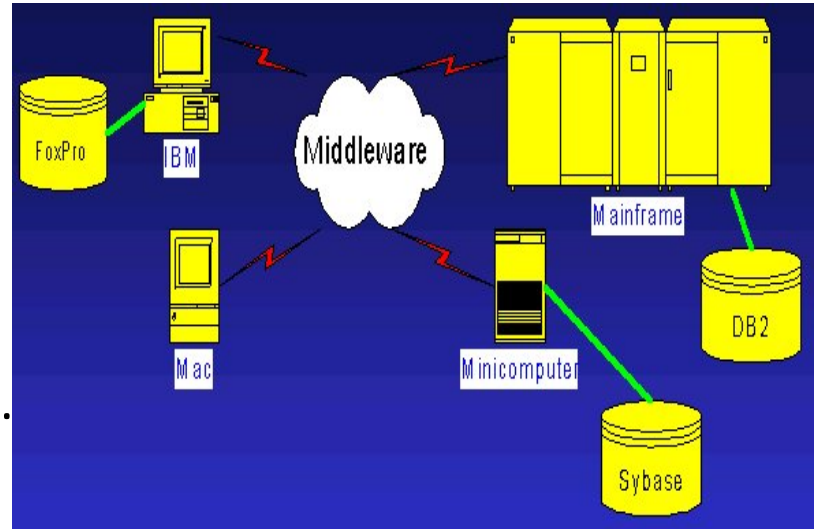
- Internet community needed to developed sophisticated "search engines" as an effective way to find things on the network.
  - Necessary due to scale and dynamic nature of network.
  - Find things by both network name *AND* data content.

Recent US Internet Map

- Lesson: as SG grows and reaches into homes to locate smart appliances and energy loads, it will face a task of similar dimensions.
  - e.g. - 400K dishwashers shipped into US market in July '09. Soon, these will be communicating, smart devices.
  - "Which network will these devices be on?"

Talking to "things" on the Internet: the Quest for Middleware

- Supporting communications between applications distributed across the network has been a *continual, daunting* task for network engineers.
  - Example apps: eCommerce, web sales, *demand response.*
  - Motivated a series of initiatives through 80's and 90's: DCOM, CORBA, SOAP, Web Services, etc. =>"Birth and death of middleware".
- Lesson: Internet constantly re-inventing how stack is used!
  - Expect large periodic changes (DCOM=> CORBA =>SOAP => REST => ?).
  - Stress scaling and complexity as critical, long term concerns.



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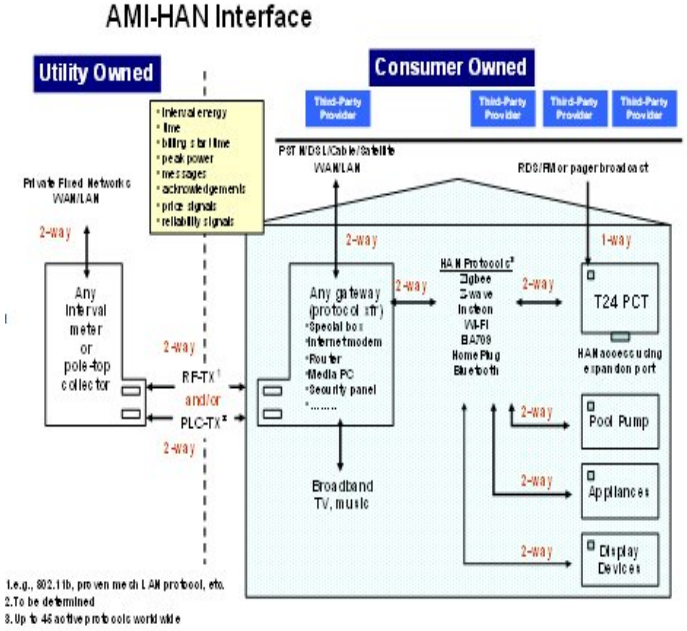
Smart Grid, Internet and Home Automation

- The largest venue for individual interactions with the SG will increasingly be the home.
  - Roughly 100M households.
- Why automate the home?
  - ~20% of current grid load....will increase with electric car market.
  - Critical to any "smart" control strategy.



- But– *the home is not a blank slate.*
  - Well established market (~20 yrs.)
  - Approx. 4M whole house systems installed along with many more partial systems (e.g. just lighting, just security, etc.)

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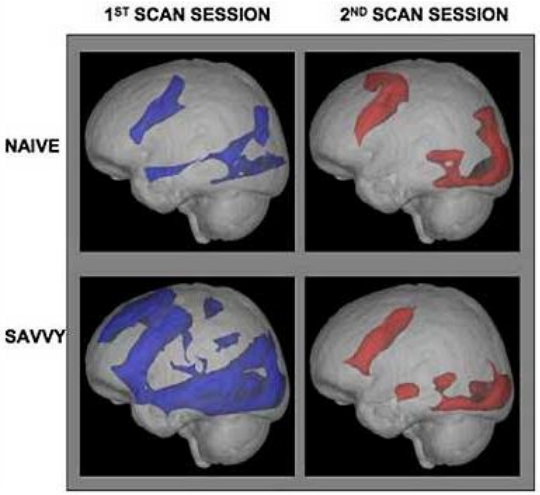
The Internet and Home Automation

- With US residential Internet access at ~75%, home automation and Internet functions are merging.
  - Ubiquitous access (Internet) + convenience and local control (home automation) = the new Smart House.
  - Many large vendors already in this space. (Google, Intel, MS, etc.)
  - User expectations are established: "access anything anywhere anytime".

- Lesson: "Certainly, the SG will use the Internet to interact with end users.....But,"
  - Will architecture meet "home automation" expectations? (e.g. recent Smart Meter data presentation issues)
  - Will data and access paths be open or proprietary?

User Skill Base in the Internet Community

- Internet users getting comfortable with IP technology.
  - BT dramatically reduces cost of DSL deployment by implementing successful customer DIY install program.
  - Hardware, software and social engineering efforts have educated users – good news for widespread technology deployments.
- Even some evidence that "savvy" Internet users show increased problem solving abilities
- Lessons:
  - Internet user community accepts and is comfortable with new technologies.
  - Leverage these skills by focusing on Internet for user interactions with SG.



UCLA Internet Surfing Brain Scan

Conclusions

- Potential scale and extent of the Smart Grid are closely matched with those of the existing Internet.
  - While a good predictor of Smart Grid success, there is still ample room for architectural mistakes.
  - Internet implementation history can provide valuable guidance: maximize flexibility and minimize complexity.
- If the entire Smart Grid vision is to be achieved, its implementation must also satisfy the group that will be its largest stakeholder – *the residential end user.*
  - This group is already intensely engaged with the Internet.
  - SG should leverage this by meeting existing Internet and home automation expectations – in essence, integrate end user activities into the Internet Community.