EEDN Seminar

Nanogrids, Power Distribution, and Building Networks

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Overview

- Nanogrids
- Power distribution generally
- Building Networks
  - relation to the ‘Smart Grid’
- Energy reporting
- Internet of Things

This is a ***work in progress***

Nanogrid Overview

- What is a Nanogrid?
- Relation to other grids
- Examples
- Implementation
- The way forward

ENERGY
EFFICIENT
DIGITAL
NETWORKS

This an initial proposal, not a final design

Examples

No communications

- Vehicles – 12 V, 42 V, 400 V, …
- eMerge – 24 V, 380 V
- Downstream of UPS – 115 VAC

With communications

- Universal Serial Bus, USB – 5 V
- Power over Ethernet, PoE – 48 V
- Proprietary systems

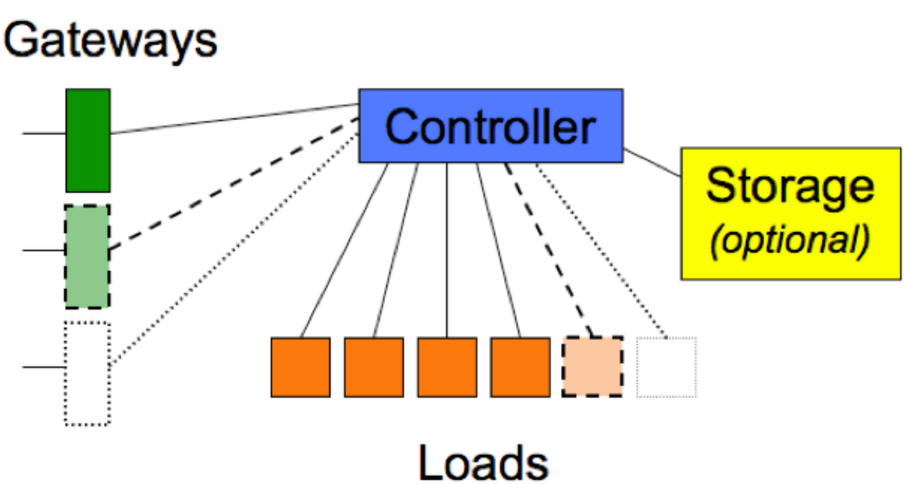
Power adapter systems

- Universal Power Adapter for Mobile Devices, UPAMD – IEEE
- *(Greenplug, Inc.)*
- Wireless technologies

What is a Nanogrid?

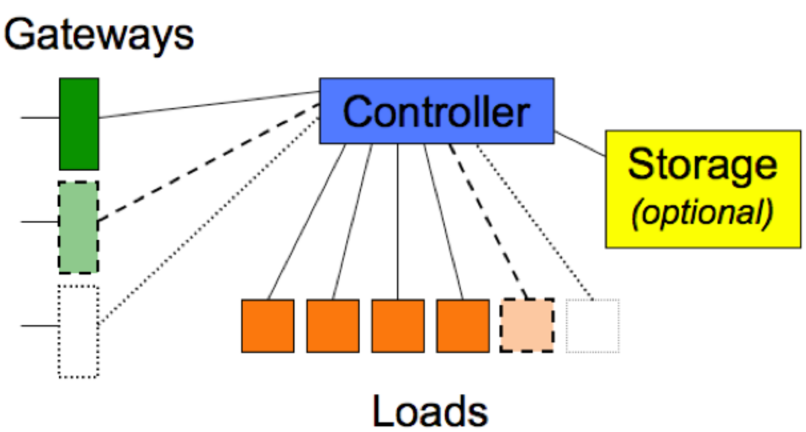
"A (very) small electricity domain"

- Like a microgrid, only (much) smaller
- Has a single physical layer (voltage; usually DC)
- May have control
- Is a single administrative, reliability, and price domain
- Can interoperate with other (nano, micro) grids through gateways



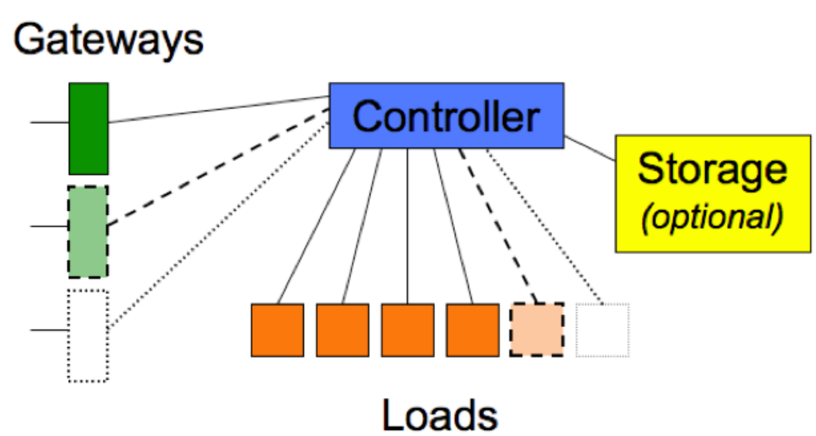
Nanogrid details

- Must have at least one load*
- Must have a gateway*
  - Can be intermittently connected
  - Supply always via a gateway
- **Only implement power distribution**
  - **Devices control themselves for functionality**
- Can be highly dynamic in connected devices, power flow quantity (and direction), …
- Range in functionality of controls, gateways
- Loads usually < 100 W, sometimes < 1 W



Controller

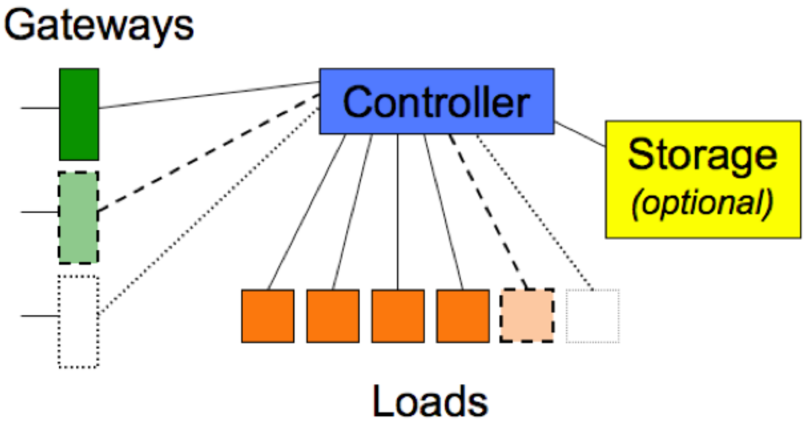
- Can have ability to grant or revoke power to loads
- Negotiates with other grids through gateways
- Sets prices
- Manages storage
- Is **<u>the</u>** authority within the grid
- (Should) Provide minimal power to loads at all times to maintain communications ability
- Deals with loads that do not communicate



Gateways

- Can be one-way or two-way (for power)
- Most functional when communications exist
- Can be to a nanogrid, microgrid, or the megagrid
- Have a capacity limit
- Exchange voltage: *???*
- Only information that passes across gateway is price, capacity, and availability

- Perhaps storage is just a (special) gateway?



Price

- Not required — but really useful
- Basic mechanism for devices to express preferences
- Can be unitary or a time series forecast
- Is local only to the nanogrid
- Used in deciding when to
  - exchange power across gateways
  - add to or withdraw from storage
- Exchange losses dictate differential ‘buying’ and ‘selling’ prices (gateway and storage)
- Gateways *may* track energy flows and prices

Relation to other grids

- Macrogrid (megagrid)
  - Large
  - No direct coordination between sources and loads
  - Oversizing and diversity enable this
- As grids get smaller
  - Potential for supply/demand imbalances increase
  - Need for coordination grows
  - Off-grid operation requires local generation or storage
  - Advances in communications technology enables coordination not before possible

Microgrids

- better integrate local (distributed) generation
- optimize multiple-output energy systems (e.g. combined heat and power, CHP)
- better integrate local storage
- provide a variety of voltages, including DC
- provide a variety of quality and reliability options.
- operate independently of the macrogrid (or connected)
- hide microgrid details from the macrogrid

Nanogrids implement only some of these

Microgrids vs. Nanogrids

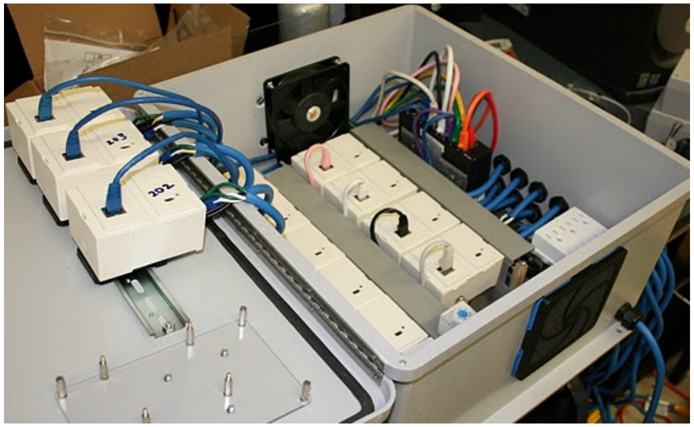
- Few
- Building/campus scale
- Multiple voltage, reliability domains
- Includes generation
- Have to deal with implementation issues

- Many
- Few connected devices
- Single voltage, reliability domain
- No generation
- Already works!

- *Bottom-up approaches are more deployable, flexible, cost-effective, functional*
- *Nanogrids can enable a “better grid” faster and cheaper than the “smart grid” (though they can co-exist)*

Inspiration

- Existing technology
- Modeling network architecture on Internet
  - Randy Katz et al., UCB; “LoCal” – local.cs.berkeley.edu
- Developing country needs; off-grid households
  - Eric Brewer, UCB; TIER – tier.cs.berkeley.edu
    Technology and Infrastructure for Emerging Regions



photos: Colombia University

Network of networks ➔ **Internet** — Network of grids ➔ **Intergrid**

Photo: Matthew Kam, TIER
School near Lucknow, India

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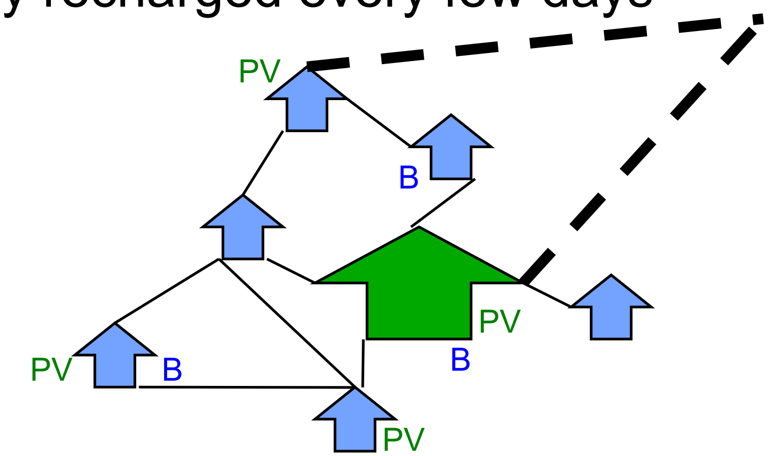
Implementation

- Will be used because they are convenient
- Enable easy sharing of (surplus) local generation
- May (or may not) have efficiency advantages
- Most NG connected to the macrogrid (intermittently)
  - Even vehicles will be
- Price mechanism ensures that all power exchanges are mutually beneficial
- Gateways have “friction” — this enhances stability
- Using same technologies in many domains ensures that they are cheap and available for very poor
  - Example: proliferation of mobile phones

Village example

- Start with single house – car battery recharged every few days
  - Light, phone charger, TV, ???
  - Add local generation – PV, wind, …
- Neighbors do same
  - Interconnect two houses
- School gets PV
  - More variable demand
- Eventually all houses, businesses connected in a mesh
  - Can consider when topology should be changed
- Existence of generation, storage, households, connections all dynamic
- Can later add grid connection



Communication

- Ideally use functional communication path for power coordination, e.g. USB, PoE
- Otherwise need simple, robust, slow physical layers
- Single physical layer for power coordination within a NG
- At gateways need standard communication
  - G.hn? Internet Zero?
  - Need single gateway protocol / physical layer
- All communication only requires data links
  - not (complicated) network infrastructure

The way forward

- Better document **existing** nanogrids
  - Capabilities, uses, …
- Define a “meta-architecture” for operation, gateways, prices
- Define specific gateways (voltage, communication)
- Define nanogrid implementation for existing technologies
- **Always** keep power distribution and functionality separate
- Identify promising applications
- Demonstrate, document, market
- Bring (more, better) nanogrids to the neediest
- Test price mechanism

Summary: Nanogrids …

… exist and are widespread

… have many advantages

- Likely better efficiency for native DC loads
- Easier (cheaper) renewables integration
- Ride on functional advantages for cost, motivation
- Benefits are immediate
- Are bottom-up and de-centralized
- Can (are) implemented only locally

… can help us quickly evolve our electricity system

… can interoperate with a smart(er) grid

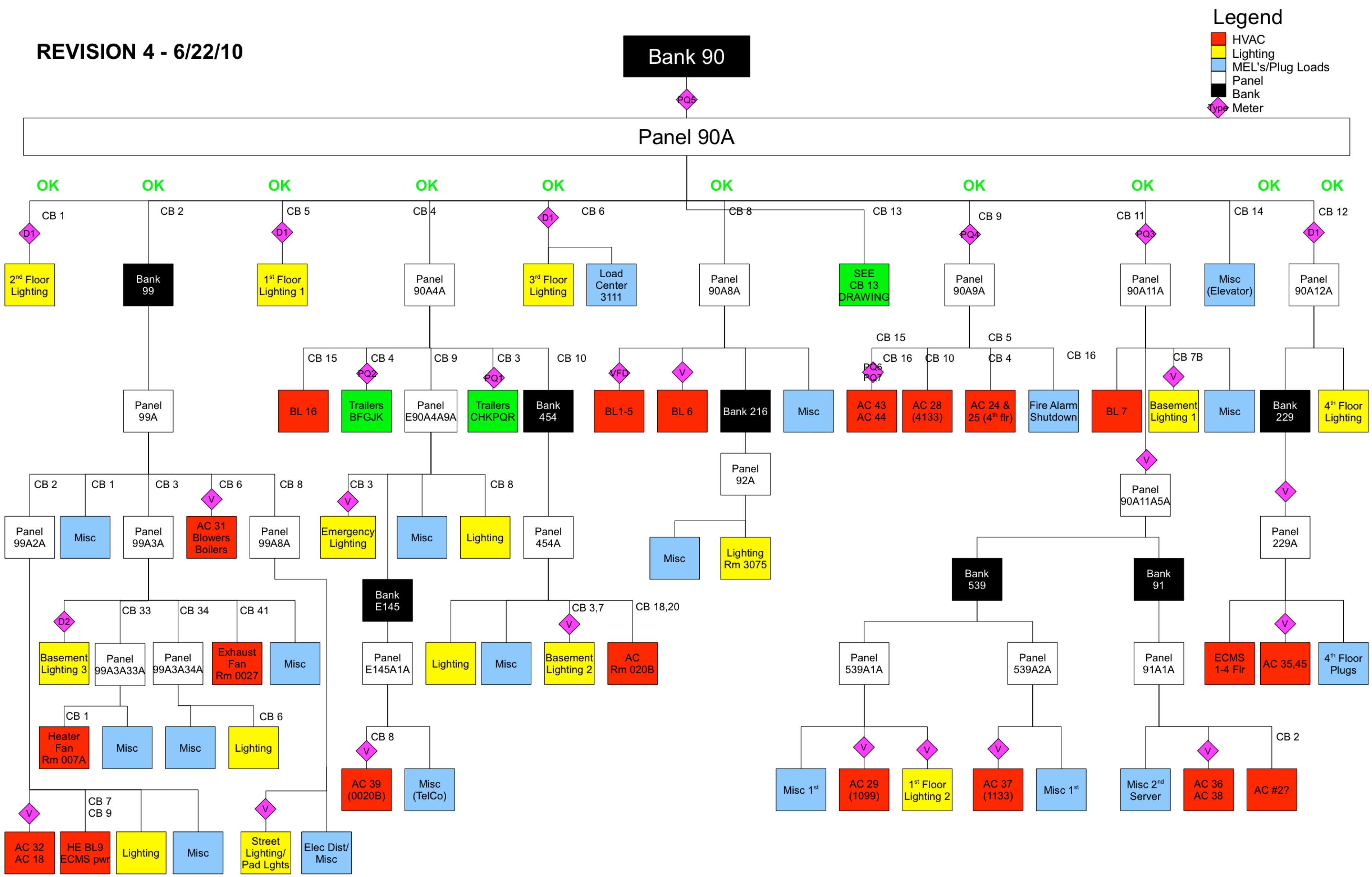
Power distribution generally

- Traditionally fairly uniform physical layer — 110, 220 VAC
- Control – only circuit breakers, switched outlets
  - No communication – no reporting
- Over-invest in capacity
- Single quality / reliability domain (excepting breakers)
- No contribution to efficiency, renewables
- Doesn’t do storage well

- My house: only circuit breakers; 120 / 240 VAC, USB
- Building 90: Generator, UPS/batteries (several), PoE (access points), 120, 208, 277, 480 VAC
  - No devices directly report power info (VFDs indirectly)

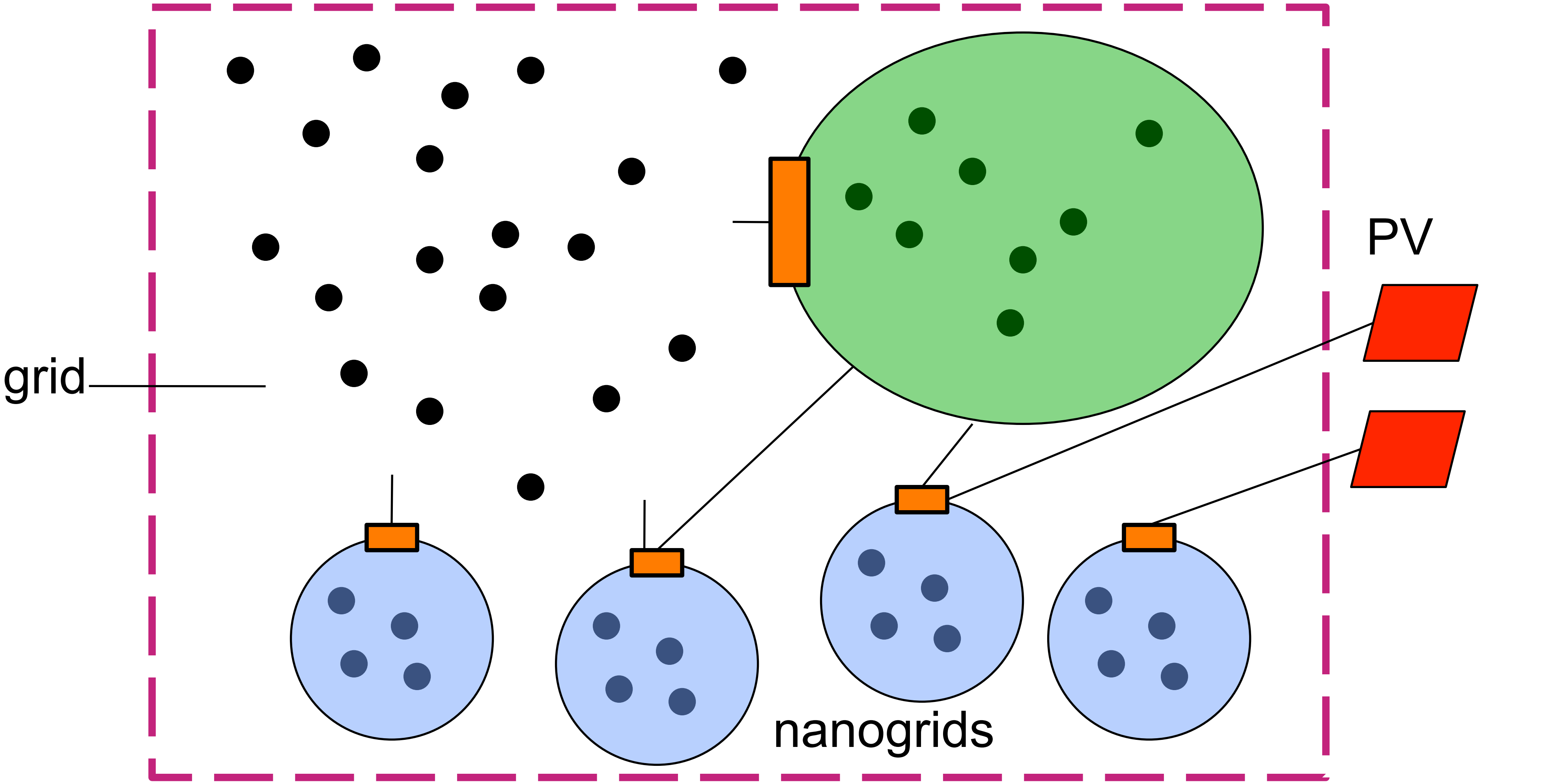
Building 90 power distribution

REVISION 4 - 6/22/10

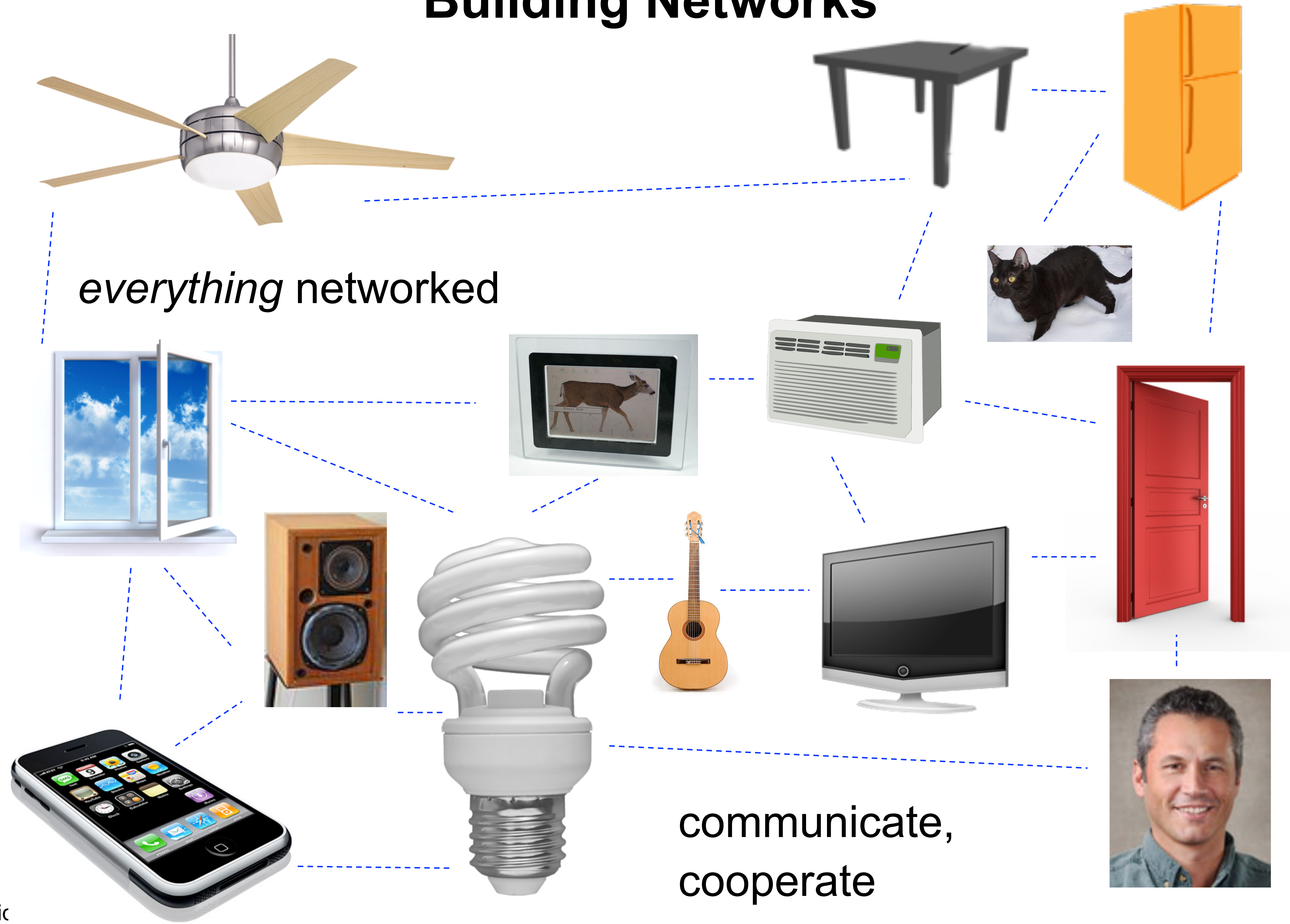


Future B90 ?

● = electricity load

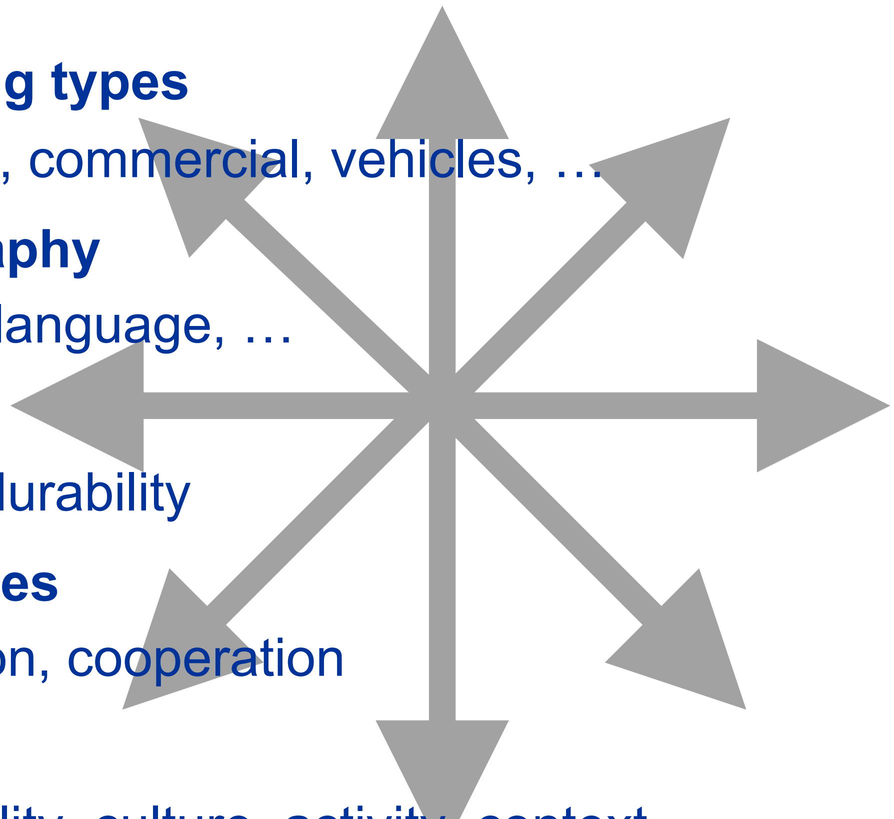


Building Networks



Universal Interoperability

Any device should work with all other objects in any space



- Across **building types**
  - Residential, commercial, vehicles, …
- Across **geography**
  - Countries, language, …
- Across **time**
  - Worthy of durability
- Across **end uses**
  - Coordination, cooperation
- Across **people**
  - Age, disability, culture, activity, context, …

“Apps for buildings”

… or “Apps for rooms” …

Building Network — Definition

A communications network that:

- enables **arbitrary communication** between any two or more devices in a space / building
- provides for **location awareness** — devices understand their own location, and their relation to others
- logically contains **people as nodes on the network** (albeit with a different set of standard interfaces)
- provides a **common data model**
  — enables interoperability among devices and people
- embraces "**universal interoperability**" as a core goal

A building can be a house, commercial building, car, …

Building Networks — Deployment

- Building networks will evolve incrementally from our IT networks
- Energy just one of many reasons to network devices
- Will use many diverse physical media
- Will use almost entirely IP data transport
- Dynamic

- Meter is a “narrow waist” — Building Network ends there
  - Price, electrons down from grid
  - Current consumption back up

Building Networks — Device Operation

- Devices operate in a bottom-up fashion
  - First, self-manage in isolation
  - Then, discover and coordinate with objects in immediate vicinity (including people)
  - Then, coordinate with building-wide entities (and consider delegating authority)
- Key inputs to operations
  - Preferences
  - Prices (current, forecast)

Building Networks vs. Smart Grid

	Building Network	Smart Grid
Scope	All devices in a building; only building side of meter	Power plant to end use devices (and everything in between)
Focus	Needs of people	Needs of electricity system
Control Strategy	Distributed, based on preferences, prices	Central, derived from existing control systems
Paradigm	Consumption	Production
Interoperability goal	Universal	Limited (*not* bldg types, countries, people, …)
Utility role	Source of (some) prices	Large; two-way communication
Timeframe	Existing & medium/long term	Short term

Building networks and power distribution

For both:

- Multiple physical layers in each building
- Can be isolated if beneficial
- Can hide details from outside connected entities
  - Can separately evolve different networks

- Enables control, reporting
- Keep technology, architecture separate

Energy / power reporting

- Always helpful to know where energy is being used
  - B90 example
- Needs to be easy, universal ➔ self-reporting
- Need ability to
  - Measure (or estimate) power
  - Accumulate
  - Communicate data
  - Report information
- Related to (but different from) control

Current / Future LBNL work

- Alan's EPS project – measure, accumulate, communicate
- IETF/eman – IP reporting

Network Layers

Layers of connectivity:

- **data link**
- **network**
- **application**

(People as nodes on network)

OSI Model Layers

1-physical

2-data link

3-network

4-transport

5,6,7-application

8-user interface

Network Layers

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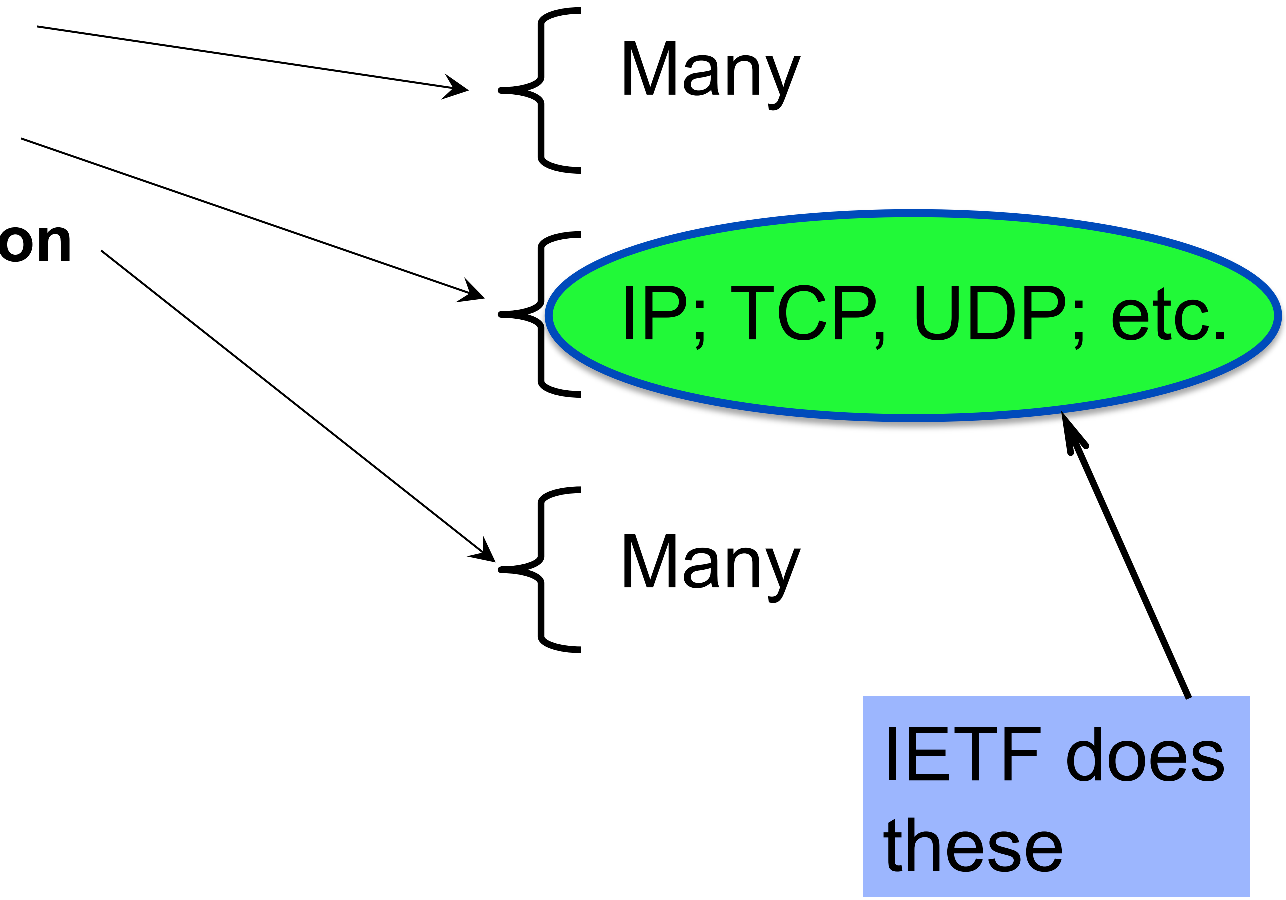


Only IP is Universal

IETF and energy reporting

- Internet Engineering Task Force (IETF, ietf.org) defines core protocols that enable Internet to operate

IF

- Energy reporting should be a basic device feature

And IF

- IP will dominate building networks (or even just be important)

Then IETF should define basic protocol for energy reporting

IETF and Energy

- 2007 – Presentation to IETF ‘70
  - Not a priority at that time
- 2008 – Interest in energy began to grow (network eqt.)
- 2009 – Discussions in “opsawg”
  (Operations Area Working Group)
- 2010
  - Internet Drafts posted
  - September – “eman” created
    “Energy Management Working Group”
  - November – first eman meeting at IETF ‘79

eman Charter

- “The basic objective of energy management is **operating** communication networks and **other equipments** with a minimal amount of energy while still providing sufficient **performance** to meet service level objectives.”
- “… energy management, which includes the areas of **power** monitoring, **energy** monitoring, and **power state** control.”
- Goal: Finish key products by Sept. 2011

- MIB – Management Information Base
  - Standard way to represent useful data / variables
- SNMP – Simple Network Management Protocol
  - Method to exchange MIB data

Eman process

My roles

- Bring energy perspective to network community
- Bring technology results to energy community
- Help develop technology

- Once standard is defined, can require in voluntary and mandatory standards; purchasing requirements
- Can be applied to **existing** products
  - Via software, firmware upgrades

Eman reporting

- Power source
- Power state
- Energy - cumulative
- May be direct, proxied, or aggregated

- Power Domain

- Identity
  - What
    - Species: e.g. switch, server, notebook PC, display, …
    - Origin: e.g. brand X, model Y (URL)
  - Who
    - Name: < text string > ???
    - Unique ID: MAC address (1st) ???

“Internet of Things” — IoT

- Applying information technology to physical world
  - (smart grid does this to electricity system)
- Electricity-using devices are things
- Most effort on “infrastructure” for this (e.g. routing)
- Building Networks one application of IoT

- Concept much more popular elsewhere

- Upcoming IETF workshop on IoT, March 25

Conclusions

Power Distribution and Building Networks

- Important, in flux
- Need to actively engage both topics
- Need to help develop new technologies
- Need to demonstrate new technologies (testbeds)

- Power reporting a key near term opportunity

Thank you

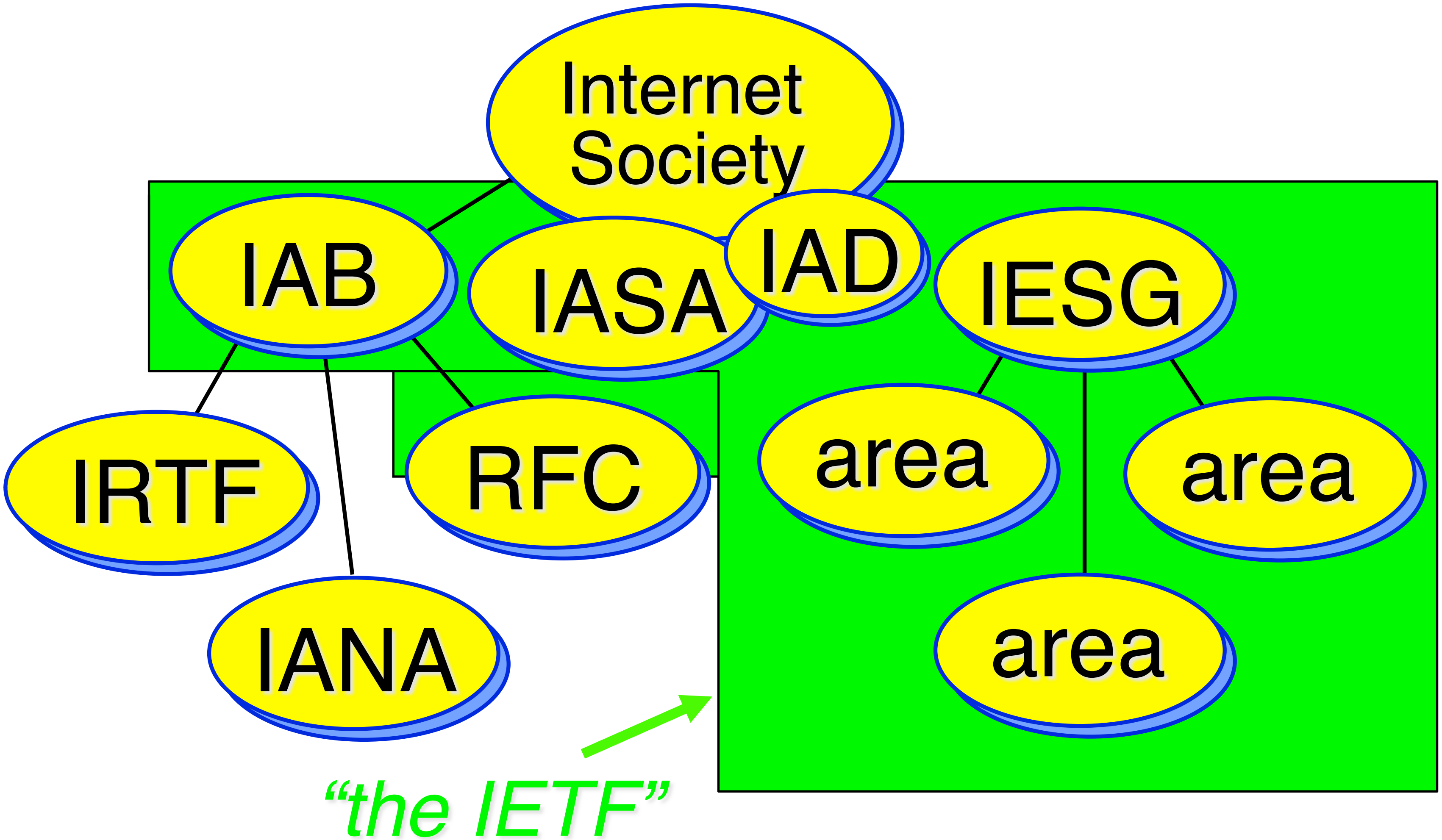
Internet Engineering Task Force (IETF)

- **"above the wire and below the application"**
  - **"IP, TCP, email, routing, IPsec, HTTP, FTP, ssh, LDAP, SIP, mobile IP, ppp, RADIUS, Kerberos, secure email, streaming video & audio, ..."**

- **Purpose: Develop protocols to enable the Internet to operate and provide useful services**
- **Structure: No members, no voting**
  - **does have working groups**
  - **"an organized activity of the Internet Society"**

- **The Internet enables us to do things not otherwise possible**
- **Core evolution of Internet occurs in IETF**

Top Level View of IETF Organization



Source: IETF