

BBN Technologies

Forty

~~Fifty~~ Research Questions in Data Communications

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Origins of this list

- A question from Bob Lucky in 2003
- Watching the community thrash somewhat on Future Internet and crafting missions for GENI
- Other fields have some tradition of creating lists of questions
 - Math:
 - Hilbert's 23 questions in 1900
 - Langlands program of 1967
 - Physics community
 - Regularly lays out multi-year plans for what to attack
- Why not try?

Collecting ideas for about 5 years

- Originally the rate of ideas came so fast I thought I'd have a paper with over 100
 - When I reached about 70 I settled on 101 as stopping point
- Then as I refined the list it started to shrink
 - Fell below 50 then below 40
 - Lately, with help from friends, I've been adding back

A list of research questions

- Worth the attention of multiple researchers
- An answer should open up substantial follow on efforts (either in research or industry or both)
- Likely to reward attention
 - no dead ends or problems we've been beating our heads against for years with no signs of potential success
- My personal list
 - Not the result of a panel
 - Not a consensus of friends
 - Purely my fault

What caused questions to drop off?

- Recall I started thinking 101 was reasonable number
- Clearly expressing the problem
 - Problems that sounded good occasionally collapsed as I tightened them up
 - Dave Patterson had a good point
- Solved or there's a good sized group working on it
 - Most problems that were dropped had been solved or had a conference/workshop/multiple research teams devoted to the problem
 - But DySpan didn't kill some spectrum work (point here is that I read the conference abstracts and sometimes found that problems remained open)
- Strong signs we're beating our heads
 - e.g. killed all-optical questions
- Lack of follow on problems
 - Usually caused reframing rather than deletion of problem
- Lack of impact
 - Again, usually caused reframing

Before we hit the list

- No promises a question is unsolved
 - Did my best to confirm this but if you decide to spend time on it, remember what you paid for this advice...
- Reminder is my list
 - Not DARPA's, NSF's, EU's, NRC's
 - One person's perspective

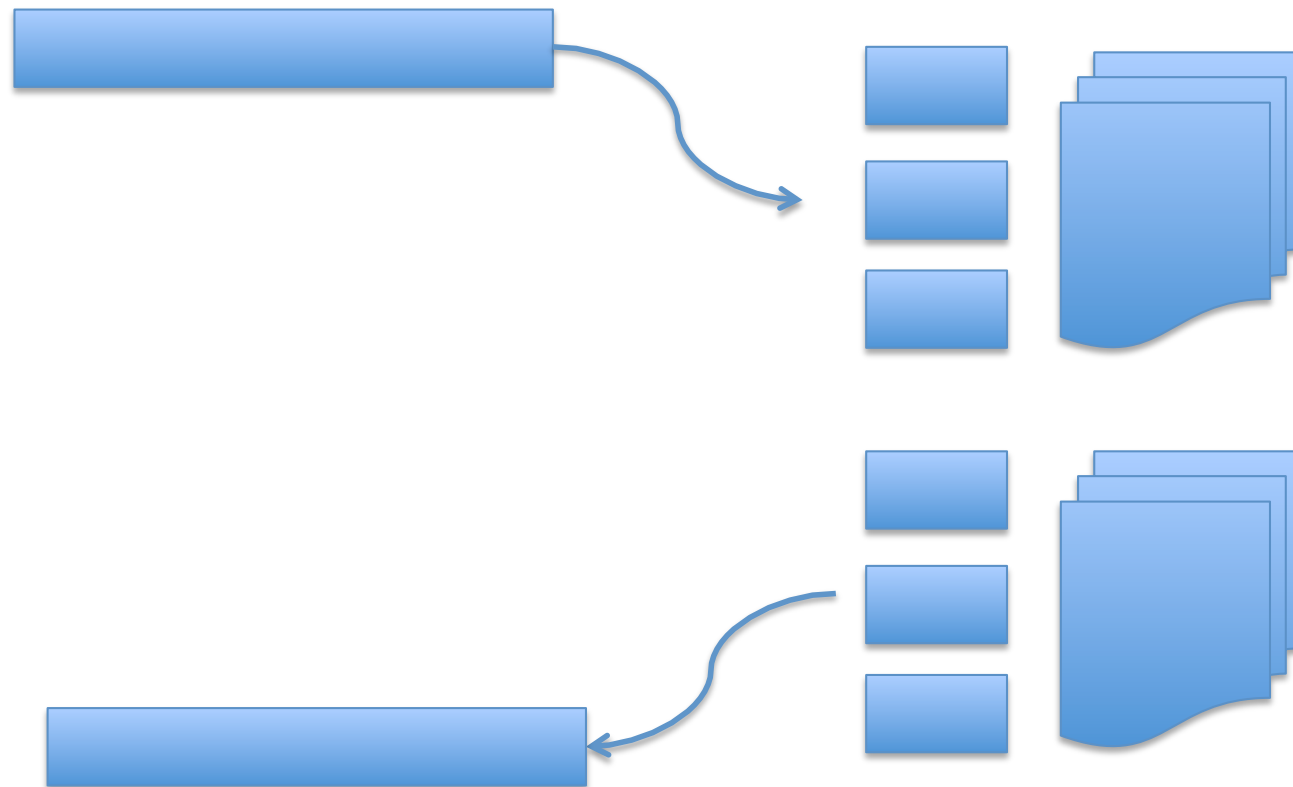
Obstacles

- An obstacle is a case where we can see, clearly, what answer the question would enable (or likely preclude)

Obstacle questions

- *How to handle parallelism inside devices?*
- *The Parallel-to-Serial (and back) problem.*
- *How to identify tussle spaces?*
- *What are the incentives for an implementation to faithfully follow the protocol specification?*
- *Create the cognitive radio!*
- *Platform-independent link and media-access specification language?*
- *Efficient backplanes with redundancy for clusters?*
- *Accurate wireless simulation?*
- *How much bandwidth can we utilize with ambitious wireless spectrum sharing and reuse?*
- *Shared security for slices?*

Parallel-to-Serial



An old (unsolved) challenge returns. A chunk of data arrives from the net and has to be divided among multiple processing cores. Data allocation may be unequal. Divide it (or combine it) in less than linear time.

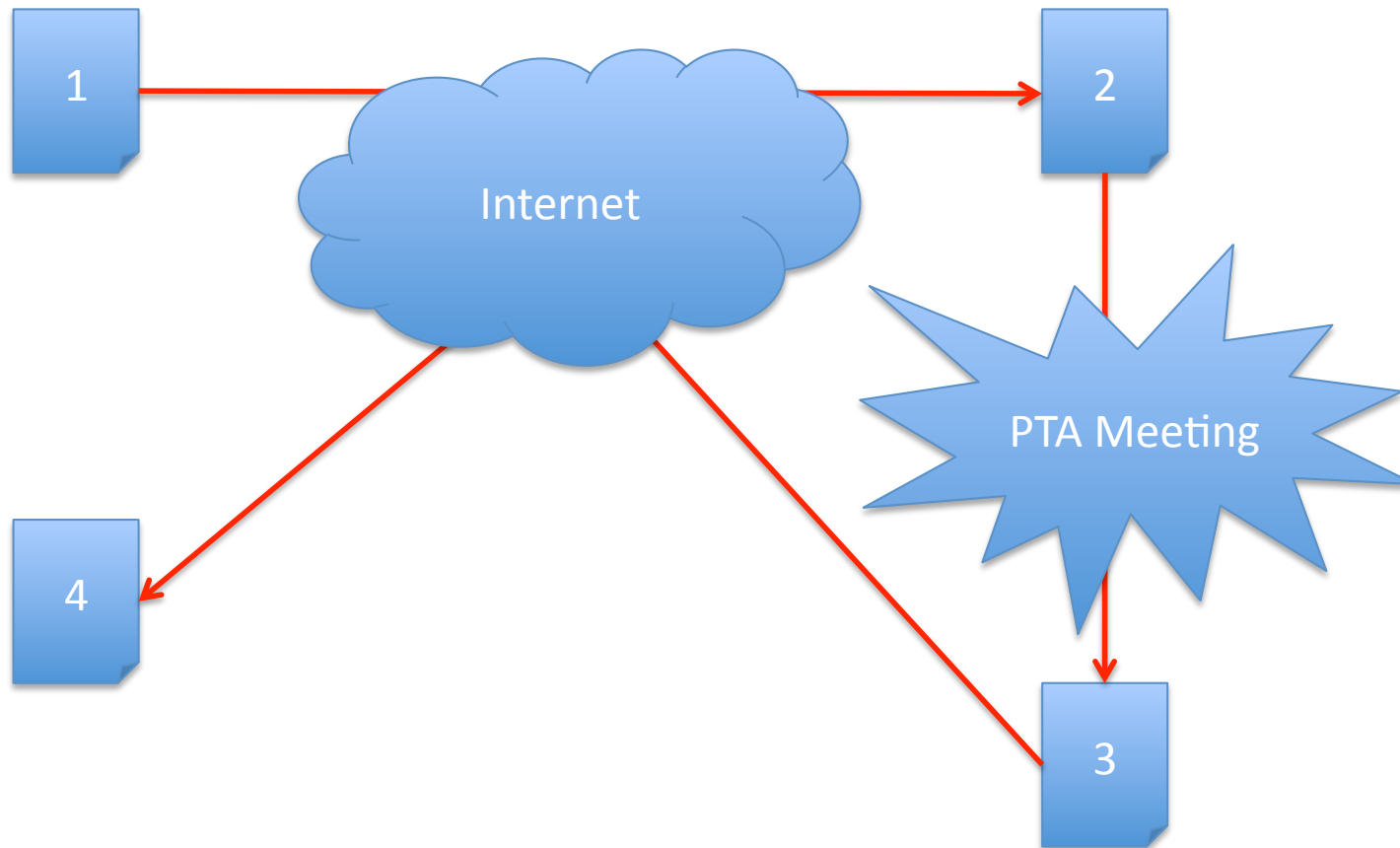
Opening new doors

- Problems that we can state but the effect of their results is unclear to us
- Standing at the door of the wardrobe...
- One of the two biggest sets of questions
 - A bit of a surprise for me
 - My PhD advisors had emphasized knowing where you're going

New door questions

- *Topology over time?*
- *Distributed quantum computing.*
- *Are there any new addressing paradigms beyond the four we know (unicast, multicast, broadcast, anycast)?*
- *Get rid of unicast addressing?*
- *Transient network addresses.*
- *Can we develop a multi-network abstraction (aka, strong network science)?*
- *Tracing across multiple types of networks.*
- *Real-time bandwidth auctions.*
- *Where should the network “waist” be?*
- *Is there a formal theory for combining protocol elements?*
- *Is there a theory of protocol decomposition?*
- *Are there cooperative protocols above the physical layer?*
- *A new paradigm for network management.*
- *Tearing down network management silos?*
- *Can we develop a new model for security analysis?*

Tracing across multiple types of Networks



A document passes through two diverse networks (one network twice).

Internet: time scale of seconds

PTA meeting: time scale of hours

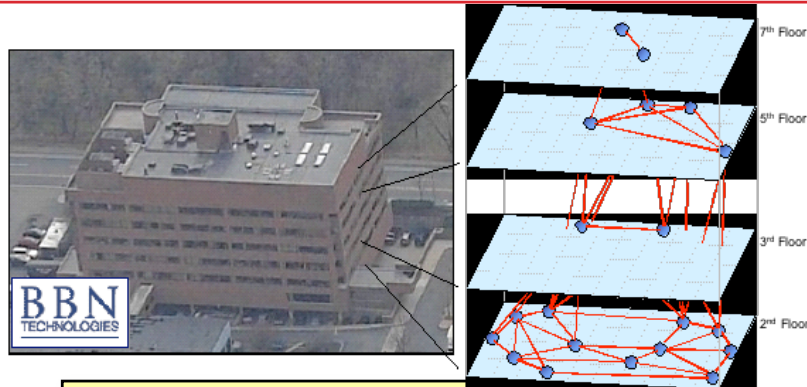
Understanding a solution space

- We've got a few tantalizing or surprising results and are trying to understand the space those results put us in

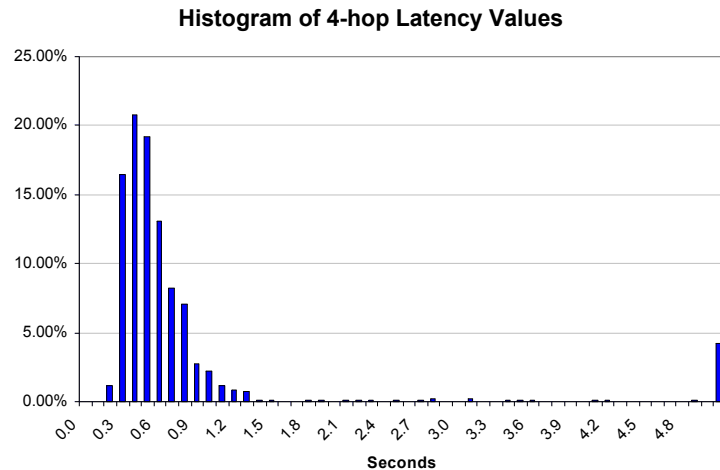
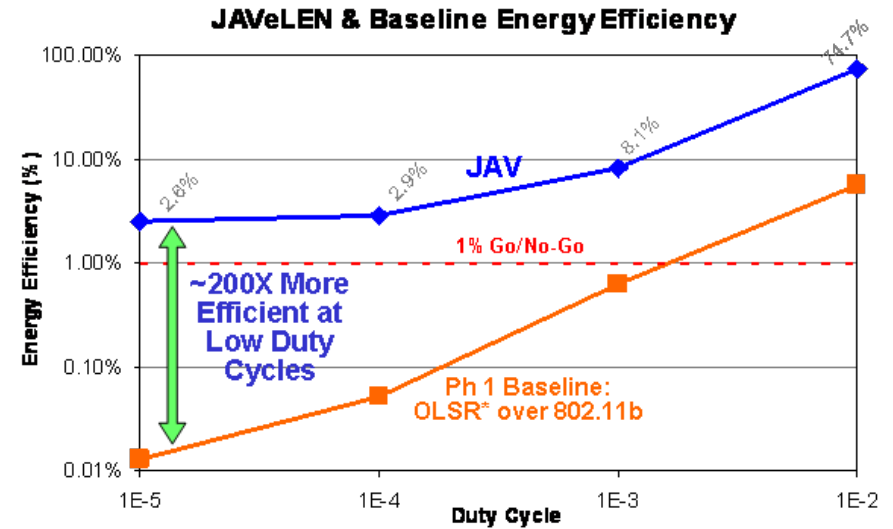
Solution space questions

- *How can we optimize energy use in a single-hop wireless network (e.g. a base station and edge node network such as WIFI or the cellular phone system)?*
- *Protocols for continuously disrupted networks.*
- *What happens if we give radios multiple power levels (on, off, and one or more intermediate power modes)?*
- *Packet headers for energy efficiency?*
- *What should be our standard traffic model for energy efficiency measurements?*
- *Designing a control channel for spectrum sharing.*
- *What is the practical capacity of a fiber?*
- *Software-defined optical devices?*
- *How much information can we extract from a time series?*
- *How do we place information in a network so that users can access it efficiently?*
- *Protocol verification.*
- *Understanding choices in dynamic spectrum use.*
- *What is the right abstraction for programming the cloud?*

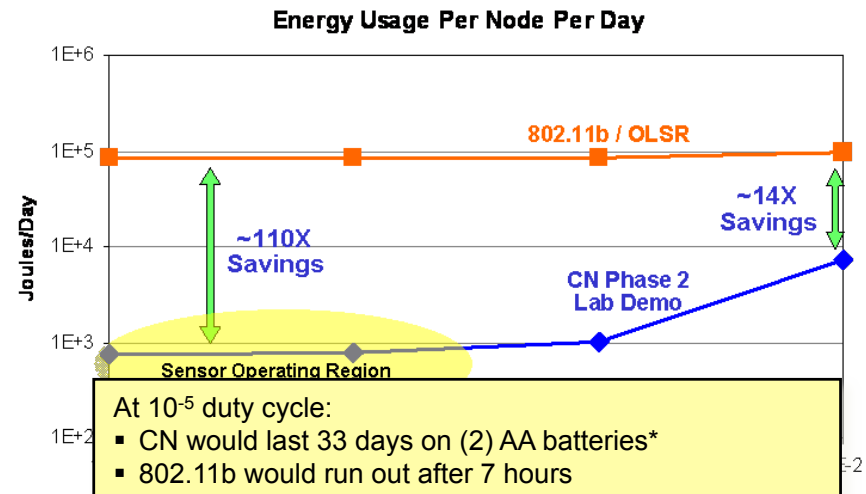
JAVeLEN Wireless Experimental Results



20-Node Indoor Lab Demo – No External Synchronization



5 node (4 hop) path avg = 1.054 sec
91% arrive < 1 sec
95% arrive < 2 sec



At 10⁻⁵ duty cycle:
 ■ CN would last 33 days on (2) AA batteries*
 ■ 802.11b would run out after 7 hours

Alternate paths

- Exploring another route to the same goal

Alternate Paths

- *Creating a richly configurable radio ASIC.*
- *Mixing electrons and photons in optical transmission equipment.*

Conclusions

- Producing a list is a far more difficult intellectual exercise than I imagined
- I'm still taking new ideas for questions!
- I hope you found this, very different from the typical tech talk, fun!