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The Past and Future Internet

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A Brief History of the Internet

- **Designed in 1972-1977**
  - **Semiconductor parts were slow and expensive.**
  - **The system was private.**
- **Radical change in the early 1990s**
  - **Advent of World-Wide Web brought new content on-line.**
  - **Opening of the system to the mass public brought new users on-line as well.**
- **An even bigger transformation is upon us.**

Present-Day Challenges

- **We're running out of addresses for IP version 4.**
- **Number of routes is increasing at an alarming rate.**
  - **Now up to 300,000 BGP prefixes.**
  - **Semiconductor parts that make fast routing possible do not follow the Moore's Law curve for mass-market parts.**

Present-Day Challenges - 2

- **Traffic growing at 50-100% per year.**
  - **Considerable uncertainty about the rate.**
  - **Private peering and paid peering emerging.**
  - **Content Delivery Networks are growing.**
- **Three billion mobile devices will join the Internet.**
- **Eight billion CPUs are sold every year**
  - **Many of them will come on-line as well.**
- **Security, spam, DDoS attacks, and viruses are challenges.**
  - **End-to-End Solutions are ineffective.**

The Congestion Problem

- **Managing bandwidth is a central design problem for any multi-user communication network.**
- **PSTN allocates bandwidth call-by-call:**
  - **Unused bandwidth goes to waste.**
  - **Congestion is a pathology: "All circuits in use."**
- **Packet nets manage bandwidth packet-by-packet:**
  - **"Congestion" is simply high utilization.**
  - **High utilization is the goal.**
  - **Contention is ongoing.**
  - **Over-provisioning is not a solution.**
  - **Economics allocate bandwidth most efficiently.**

The Routing Problem

- **Meyer, Zhang, and Fall, "Report from the IAB Workshop on Routing and Addressing," RFC 4984, 2006:**
  - ***"[We] need to devise a scalable routing and addressing system, one that is scalable in the face of multihoming, and that facilitates a wide spectrum of traffic engineering (TE) requirements."***
- **This system has not been developed**
  - **Probably can't be developed around IPv4 or IPv6.**
- **Where will the New Architecture come from?**
  - **NSF funding NEWARCH, GENI, and FIND**
  - **Some other country**
- **Many testbeds, no new architecture**
  - **We're not there yet**

Most Important Trends

- **Wireless**
- **Video**
- **Machine-to-Machine**
- **Low-Latency Services like Gaming**

Wireless Internet Access

- 1.6 billion users on Internet today vs. 4.5 billion mobile devices
- World-wide Spectrum Crunch
  - Especially tight in the U. S. because of government inaction.
- Diverse Service Model
  - Telephony is a high-value application.
  - Wireless devices need at least three service levels.
- Pervasive Connectivity
  - Greater cooperation between carriers
- Enables entirely new vistas for application development.
  - Location-aware services
  - Finding people and things
  - Need for much better security.

Promising Technologies

- **Beam-Forming**
  - **Allows same frequencies to be re-used**
  - **Troublesome for aggregation.**
  - **Still a paper tiger, but work is underway for SDMA.**
- **Multiple-Use on Digital Networks.**
  - **A crude form is found in the White Spaces order.**
  - **A lot more work to be done.**
  - **Time scale isn't days, it's milliseconds.**
- **Bandwidth brokering and bartering.**

Emerging Applications

- **Advanced User Interfaces**
  - **Driven by Speech, Location, and Gesture**
  - **Keyboard-free**
- **Multiple simultaneous communication modes**
  - **GPS + Bluetooth + NFC + WiFi/3G/4G**
- **Enhancing the Power of Social Networks**
  - **Automatically Capture and Share Location**
  - **Capture and Share transactions**
- **Integration of preferences, calendars and social graph**
  - **Frequent communications, not a great deal more data.**
  - **Aggregation by base station in the home, office, or car.**
- **The Goal of Much of this is "Serendipity:"**
  - **Things you're glad to know but didn't know to seek.**

Thank you.

See my paper, "Designed for Change: End-to-End Arguments, Internet Innovation, and the Net Neutrality Debate," at itif.org.

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