Broadband Technologies, Part 1: Needs, Capabilities, and Metrics

California Public Utilities Commission - Broadband Caseworkers
March 2023

California Public Utilities Commission

Overview of Caseworker Seminars

Level 1	Level 2	Level 3
Business Considerations: • Services, customer segments, market participants • Business/ownership models	**Business Considerations:** • Funding strategies and fundamentals of finance • Intro to business plans	**Business Considerations:** • Business plans, revenue sources, and forecasting • Marketing and strategic planning
Technology Talks: • Overview of broadband technologies • Definitions, descriptions, graphics	**Technology Talks:** • Cost modeling/resources required to deploy broadband • Strengths/weaknesses of different technologies	**Technology Talks:** • Best practices for deploying and operating broadband • IRUs, pole attachments, easements, etc.
Policies and Tools: • State/federal funding overview • CPUC role and available tools (maps/data)	**Policies and Tools:** • Regulatory considerations and best practices for permitting • Timeline for accessing grant opportunities	**Policies and Tools:** • Using the Federal Funding Account + Loan Loss Reserve • Data collection, mapping, and reporting requirements

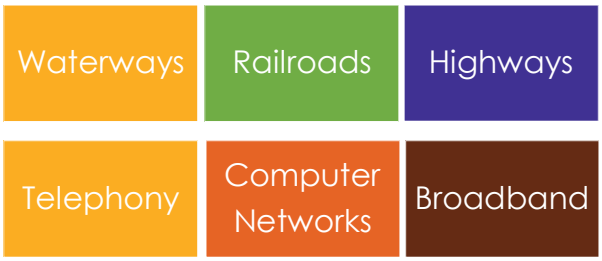
Goal: *A community that completes the seminar series will be prepared to acquire grants and subsequently develop a successful broadband network.*

Technology 101 Seminar Agenda

- Importance of Broadband
- Evolution of Broadband and the Internet
- How Broadband is Delivered
- Broadband Metrics
- Last Mile Broadband Access Options
- How Much Speed do Users Require?
- Discussion

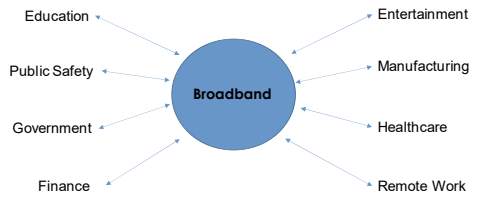
Pillars of the Modern Economy

Broadband is at the heart of the dramatically growing digital economy



Why Broadband is Critical

Society relies on broadband connectivity



Why Broadband is Critical

- **Workforce Development –** Broadband enables job training, education, and more employment opportunities
- **Economic Development** - Broadband enables towns, regions, and states to develop, attract, retain, and expand job-creation. It enables new business growth and the expansion of existing businesses into new markets.
- **Transportation –** Enables technologies that can alleviate congestion, enhance road safety, and reduce the environmental impact of transportation
- **Digital Literacy –**It is increasingly difficult to apply to jobs or access government services without digital literacy. Those who do not have access to the Internet are at a disadvantage in the academic arena and the increasingly competitive labor market.
- **And More –** Broadband provides countless benefits in agricultural technology, environmental monitoring, emergency services, telehealth, and more.

Why Broadband for All is Critical

Broadband is not everywhere….yet

- California has more unserved households than any other state in the nation.
- 52.4% of Californians actively use broadband at the modern benchmark speed of 100 Mbps.
- 51.3% of rural households lack any broadband service at 100 Mbps.
- 28.4% of households on Tribal Lands lack any broadband service at 100 Mbps.

Importance of Broadband Discussion

- What are the most important uses for broadband in your community?
- What kinds of community groups are advocating for better broadband in your community? Healthcare, schools, businesses?

- Follow-up questions can be sent to BroadbandCaseworkers@Cpuc.Ca.Gov

Broadband and the Internet

Relevance of the internet to broadband services

- Broadband is inextricably tied to the internet
- Definition of the in·ter·net:

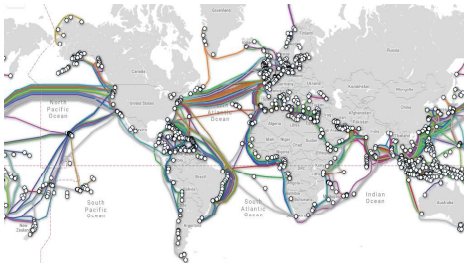
/ˈin(t)ərˌnet/

noun

  - a global computer network providing a large variety of information and communication facilities, consisting of interconnected networks using standardized communication protocols.

- Internet facilitates connectivity of computer systems operated by public and private sector organizations of small and large scale
- Public internet requires high-capacity links between computer centers

The internet backbone interconnects the world with undersea fiber optic cables



- Hundreds of "landing sites" connect fiber optic cables stretching thousands of miles under the seas
- The landing sites connect to major fiber routes on land
- International fiber routes are operated by private companies

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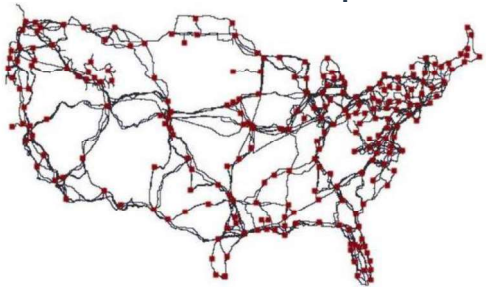
A national internet backbone interconnects data centers and connection points



- Internet backbone is analogous to interstate highway system
- Interconnection points mostly in major cities and operated by corporations or nonprofits
- Backbone fiber operated by private companies– Verizon, Lumen, Zayo as well as Facebook

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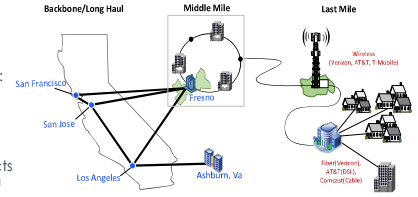
Broadband Building Blocks - Connectivity

Long Haul, Middle Mile, Last Mile

- **Long Haul:** High-capacity connections between exchange points:
  - Backbone: high-capacity connections between exchange points and hubs
  - Exchange Points and data centers: Interconnection points for service providers
  - Hubs: traffic aggregation from last mile and middle mile
- **Middle Mile connections**: Interconnects local service providers with hubs, data centers, and other carriers
- **Last Mile connections**: Connectivity to the end-user by fiber, cable (coax), wireless, or a combination of these

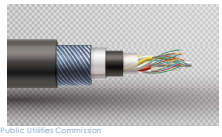


Fiber cables are the backbone of information highways

- Each fiber has a potential bandwidth of many hundred Terabits.
- Practical fiber links use a fraction of their potential capacity (800 Gbps – 15 Tbps)

- Individual fibers are packaged in rugged cables ranging from 0.2 to 2 inches in diameter:
  - 24 -144 fibers per cable (for last-mile connections, middle mile, long haul)
  - 288 – 864 fibers per cable (for middle mile, long haul)
  - 864 -6912 fibers per cable (for data center interconnects)

- Cables may be placed underground in conduits providing life spans of 30+ years



EVOLUTION OF BROADBAND DELIVERY

The term "broadband" means "high speed internet access"

Broadband speeds, capabilities and importance to society has evolved since the internet emerged in the early 1990's

- **Dial-up**: Homes/businesses connected to the internet over telephone lines by dialing the number of the service provider via modem. Called "narrowband" because the bandwidth is narrow, slow speed – **Late 1980's – Mid 1990's**
- **Always-on**: cable-TV companies provided faster service that was "on" all the time without using a phone line. The cable company used its last-mile video network to also connect customers to the internet – **Late 1990's**
- **Digital Subscriber Loop (DSL)**: phone companies introduced technology that was also "on" all the time over copper wires, faster than the old dial-up technology, but had limitations with wide coverage – **Late 1990's- early 2000's**
- **Cellular Generations**: cellular providers began to offer mobile internet (2G and 3G), though it was much slower than the cable and phone company services – **Early 2000's**
- **Fiber to the Premises (FTTP)**: High speed communication services to end users started to shape the future of telecommunications - **~ 2005**

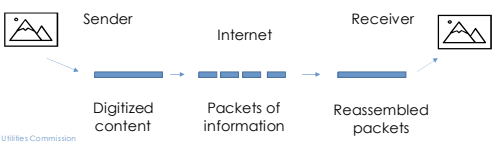
Broadband Evolution Discussion

- How has the internet changed during your career?
- Do you have fiber here in any neighborhoods? What effects have you seen from introducing fiber?
- How much of the evolution of communications technology do you remember? Dial-up modems? DSL?
- What's the cell coverage like in your area?

Follow-up questions can be sent to BroadbandCaseworkers@Cpuc.Ca.Gov

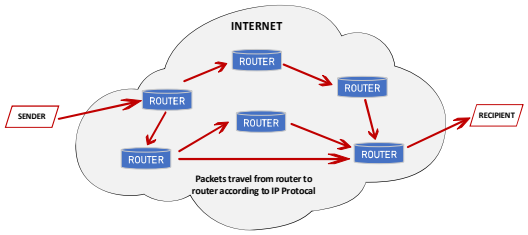
How information moves around the internet

- Internet Protocol (IP) is the standard set of rules used worldwide by internet devices that ensure equipment and software will work together on the internet (known as interoperability)
- Information travels in "packets"
- Packets include the **destination address** (or IP Address) of the intended recipient and are "routed" along the internet through a series of hubs and data centers before it lands on its final router at the premises of the recipient



How information moves around the internet

Packets are routed from source to destination using layer 1 -3 protocols



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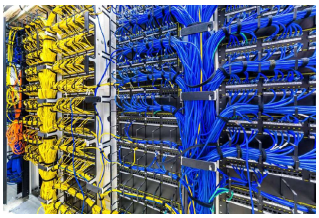
Engines of broadband connections

- **Enormous routers in data centers** and at and internet connection points contain tables of all IP addresses and direct the packets in the right direction– with the routers constantly learning new addresses
- **Small routers in your house** and direct the packets between your devices and to your internet service provider



How Broadband is Delivered Discussion

- What are the equivalent terms for each of the following in the world of physical letters and packages? Is there another metaphor that you find helpful?
  - Packets
  - Routers
  - Internet Protocol
  - IP Address

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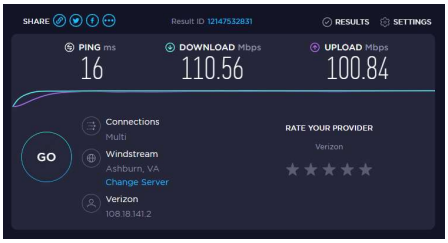
Broadband Key Metrics

Four performance parameters characterize the broadband experience

- **Download speed:** Rate at which user receives information
- **Upload speed:** Rate at which user can transmit information
  - Download and upload speeds are measured in megabits per second (Mbps)or gigabits per second (Gbps) (25Mbps/3Mbps, 100 Mbps/20Mbps, 1Gbps/1Gbps)
- **Latency:** Time delay between the sender and recipient devices
  - Typical range of 20 milliseconds to microseconds
- **Jitter**: Time variations in arrival of information packets
  - Measured in milliseconds
  - Most relevant for real-time applications (e.g., teleconferencing, video streaming)

Speed test

- One means of testing your internet connection
- Packets travel from your computer to a computer in a data center
- Quick burst of data in both directions measures connection speed, travel time (ping)
- Not perfect: May be hard to separate problems with your computer, Wi-Fi, or service provider



Run your own internet speed test: Speedtest by Ookla - The Global Broadband Speed Test

Broadband service tiers

Speed and amount of data are subject to contracts with last mile provider

- **Tiered speed service model**:
  - Most operators offer various speed tiers (100/20 Mbps, 400/50 Mbps, 1/1 Gbps etc.)
  - Flat rate, according to tier pricing
- **Data usage:**
  - **Unlimited data at flat rate:**
    - Typically offered by default (except mobile data)
    - At times of congestion, heavy users may be deprioritized (fair share concept)
  - **Metered data:**
    - Subscriber selects a monthly data package with a data cap
    - Exceeding the data ceiling may result in added usage fees, substantially diminished data throughput thus encouraging customer to change data plan
- **Average data traffic per household and month: 600 – 1000 Gigabytes (= 4800 - 8000 Gigabits)**

Broadband Metrics Discussion

- Are upload and download speeds significantly different in your community? Is it a problem for your household?
- Any questions about bits, bytes, kilo/mega/giga/tera, and storage vs. Transfer?
- When do you notice latency or jitter in your connection?
- Which speed test(s) have you used in your community surveys?

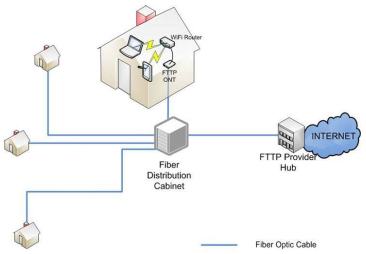
Follow-up questions can be sent to BroadbandCaseworkers@Cpuc.Ca.Gov

LAST MILE BROADBAND ACCESS OPTIONS

Fiber to the premises (FTTP)

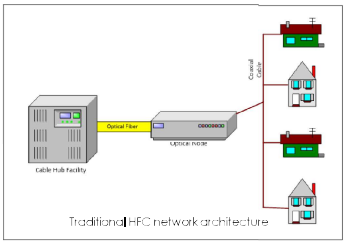
Passive Optical Network (PON) Architectures

- Pros/Cons:
  - Require no field electronics (high resiliency)
  - Interference-free
  - Access speeds limited only by electronics at hub and customer sites
  - Easy upgrade paths to higher speeds (1 Gbps ….100 Gbps)
  - Low maintenance cost
  - Time-consuming construction



Coax/cable internet access

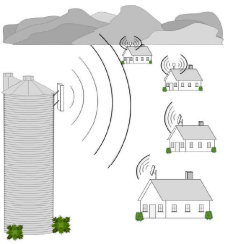
- Legacy technology, used by traditional cable companies
  - Designed for TV communication– mostly download
  - Architecture implemented as hybrid fiber/coax network (HFC)
  - Data links based on DOCSIS standards
- Pros/Cons
  - Current standards max out at 1Gbps/100Mbps
  - New standards may allow 5Gbps/5Gbps
  - More difficult to upgrade cable networks than fiber
  - Less resilient due to plant power requirement
  - High maintenance cost



(DOCSIS, short for "Data Over Cable Services Interface Specification" is a suite of protocol standards)

Fixed wireless internet access

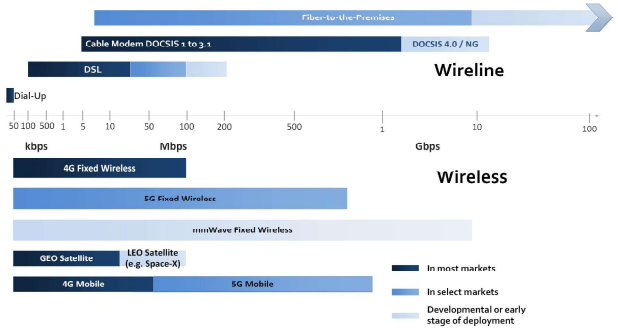
- Last mile wireless broadband service that uses fixed antennas to transmit data to homes or businesses up to a few miles away
- Spectrum typically is a mixture of licensed (3.5 GHz (CBRS), and unlicensed (2.4 GHz, 5 GHz, 60 GHz)
- Pros/Cons
  - Time to market, fast implementation
  - Good options for rural areas with no access to fiber/coax infrastructure.
  - Performance is inconsistent and will depend on subscriber density and obstacles that could block line of sight and limit transmission
  - Spectrum is limited
  - Less "future proof" (requires upgrades every 4-6 years to keep pace with technology changes)



Satellite internet access

- Well-established satellite Internet has traditionally been provided by Geo-stationary satellites
- New high-capacity Low Earth Orbiting (LEO) Internet now available (e.g., SpaceX/Starlink and others)
- Pros/Cons
  - Access in rural, remote areas
  - LEO Data rates: 100/20 Mbps target today, future: up to 500 Mbps down
  - LEO Latencies comparable to fiber:20 ms -60 ms
  - GEO satellite latency approx. 250 - 600 ms
  - High capacity LEO's still in deployment mode
  - Expensive, High maintenance costs
  - Lack capacity to serve densely populated areas

Bandwidth comparison of broadband technologies



How much speed do end users require?

Typical needs of a family of four

Bandwidth: the amount of data (bits) or volume of information transmitted over an internet connection in a given amount of time

	PEAK BANDWIDTH UTILIZATION TYPICAL FAMILY OF FOUR (DAYTIME)	TOTAL DOWNLOAD / UPLOAD
x2	Tele-Work /Tele-Health Video Conferencing (4 Mbps / 4 Mbps per user)	8 Mbps / 8 Mbps
x2	Tele-Learning Remote Classroom (4 Mbps / 4 Mbps per user)	8 Mbps / 8 Mbps
x1	HD Streaming Video Applications (Netflix, Disney+, etc.) (5 Mbps / 0.2 Mbps per stream)	5 Mbps / 0.2 Mbps
x10	Home security (Ring, etc.) and other household smart devices (Alexa, Cortona, etc.) (2 Mbps / 2 Mbps for system)	2 Mbps / 2 Mbps
	TOTAL BANDWIDTH USE (rounded)	23 Mbps / 18 Mbps

	PEAK BANDWIDTH UTILIZATION TYPICAL FAMILY OF FOUR (EVENING)	DOWNLOAD / UPLOAD
x1	Online Video Gaming (3 Mbps / 0.5 Mbps per user)	3 Mbps / 0.5 Mbps
x2	Streaming Video Applications (1 UHD at 25 Mbps / 0.2 Mbps, 1 HD at 5 Mbps / 0.2 Mbps per stream)	30 Mbps / 0.4 Mbps
x3	Surfing Internet (1.3 Mbps / 0.3 Mbps per user)	4Mbps / 1.0 Mbps
x10	Home security (Ring, etc.) and other household smart devices (Alexa, Cortona, etc.) (2 Mbps / 2 Mbps for system)	2 Mbps / 2 Mbps
	TOTAL BANDWIDTH USE (rounded)	39 Mbps / 4 Mbps

Future needs will be much higher

	FUTURE PEAK BANDWIDTH UTILIZATION TELEWORK/TELELEARNING (DAYTIME)	TOTAL DOWNLOAD / UPLOAD
x1	Home business operations (20 Mbps / 20 Mbps per user)	20 Mbps / 20 Mbps
x1	Telework / telehealth video conferencing (6 Mbps / 6 Mbps per user)	6 Mbps / 6 Mbps
x1	UHD streaming video applications (25 Mbps / 0.2 Mbps per stream)	25 Mbps / 0.2 Mbps
x2	Distance learning remote classroom (6 Mbps / 6 Mbps per user)	12 Mbps / 12 Mbps
x1	Home security (Ring, etc.) and other household smart devices (Alexa, Google Nest, etc.) (4 Mbps / 4 Mbps per home)	4 Mbps / 4 Mbps
X 1	Augmented/virtual reality HD advanced level (400 Mbps / 400 Mbps per user)	400 Mbps / 400 Mbps
	TOTAL BANDWIDTH USE (rounded)	467 Mbps / 442 Mbps

	FUTURE PEAK BANDWIDTH UTILIZATION MULTI-GENERATIONAL FAMILY OF ELEVEN (EVENING)	TOTAL DOWNLOAD / UPLOAD
x2	Online video gaming (4 Mbps / 2 Mbps per user)	8 Mbps / 4 Mbps
x3	UHD streaming video applications (25 Mbps / 0.2 Mbps per user)	75 Mbps / 0.6 Mbps
x3	Surfing Internet (2 Mbps / 0.7 Mbps per user)	6 Mbps / 2 Mbps
x1	Video chat (Zoom, etc.) (6 Mbps / 6 Mbps per user)	6 Mbps / 6 Mbps
x1	Home security (Ring, etc.) and other household smart devices (Alexa, Google Nest. etc.) (4 Mbps / 4 Mbps per home)	4 Mbps / 4 Mbps
X 3	Augmented/virtual reality HD advanced level (1,200 Mbps / 1,200 Mbps per user)	1,200 Mbps / 1,200 Mbps
	TOTAL BANDWIDTH USE (rounded)	1,299 Mbps / 1,217 Mbps

QUESTIONS AND DISCUSSION

- What new factoid did you learn during this session?
- What part of this technology overview do you want to know more about?
- Who configures your home wireless router? Do they get extra dessert?

please contact us at BroadbandCaseworkers@Cpuc.Ca.Gov

Preview of Parts 2 and 3 of Broadband Technologies

Part 2: Planning and Designing a Broadband Network

- Planning Phases
- Capital Cost Modeling
- Designing and Permitting

Part 3: Constructing and Operating a Broadband Network

- Deployment, Procurement, and Construction Strategies
- Operations Cost Modeling
- In-house and Outsourced Functions

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