

# Wireless Access for Next-Generation Internet

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# Some attributes of the Next-Generation Internet

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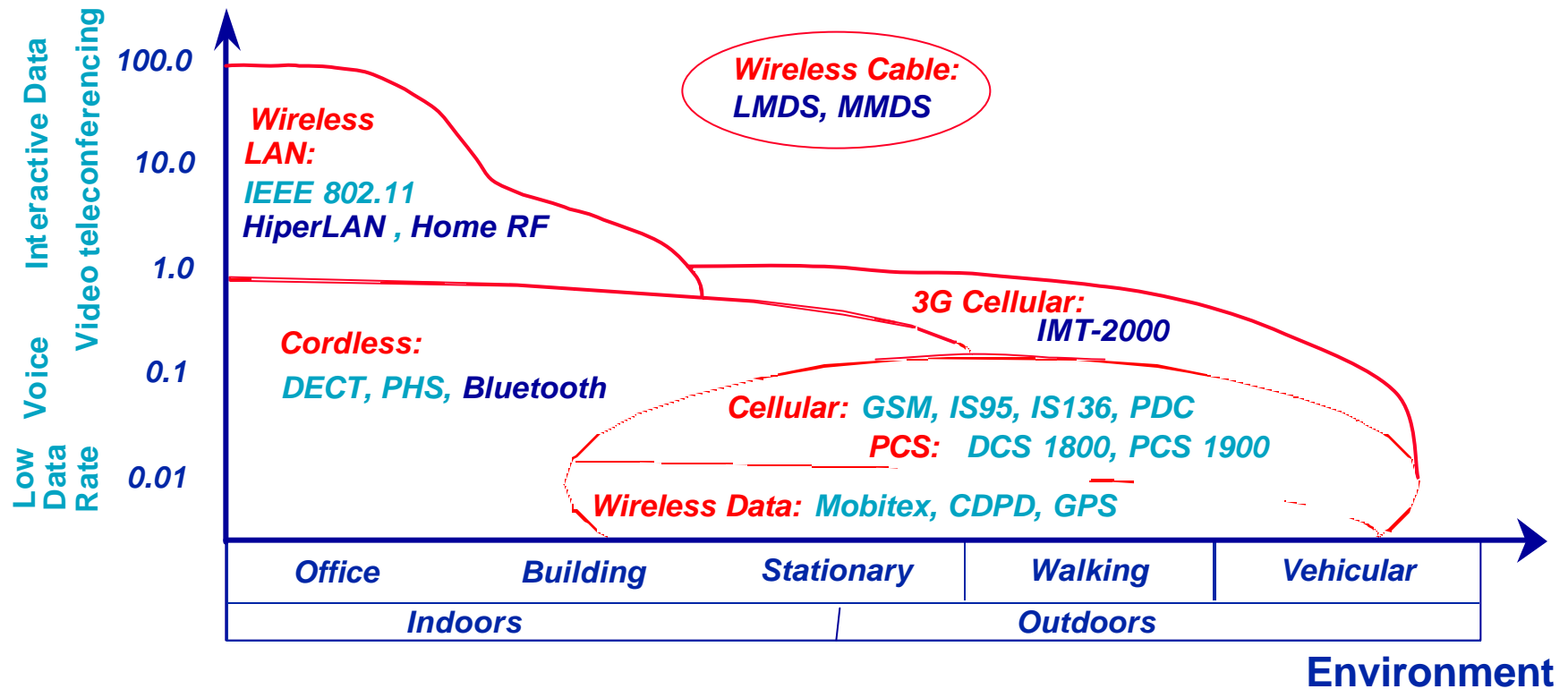
File Name-9/14/00- 2

- Heterogeneous network and access
- Realtime services
- Deeply networked
- Pervasive
- Mobile
- **Broadband**

# Evolution of Wireless Technology

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## Information Content (Mbps)



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# Accelerated Growth of High-Speed Wireless Data Networks

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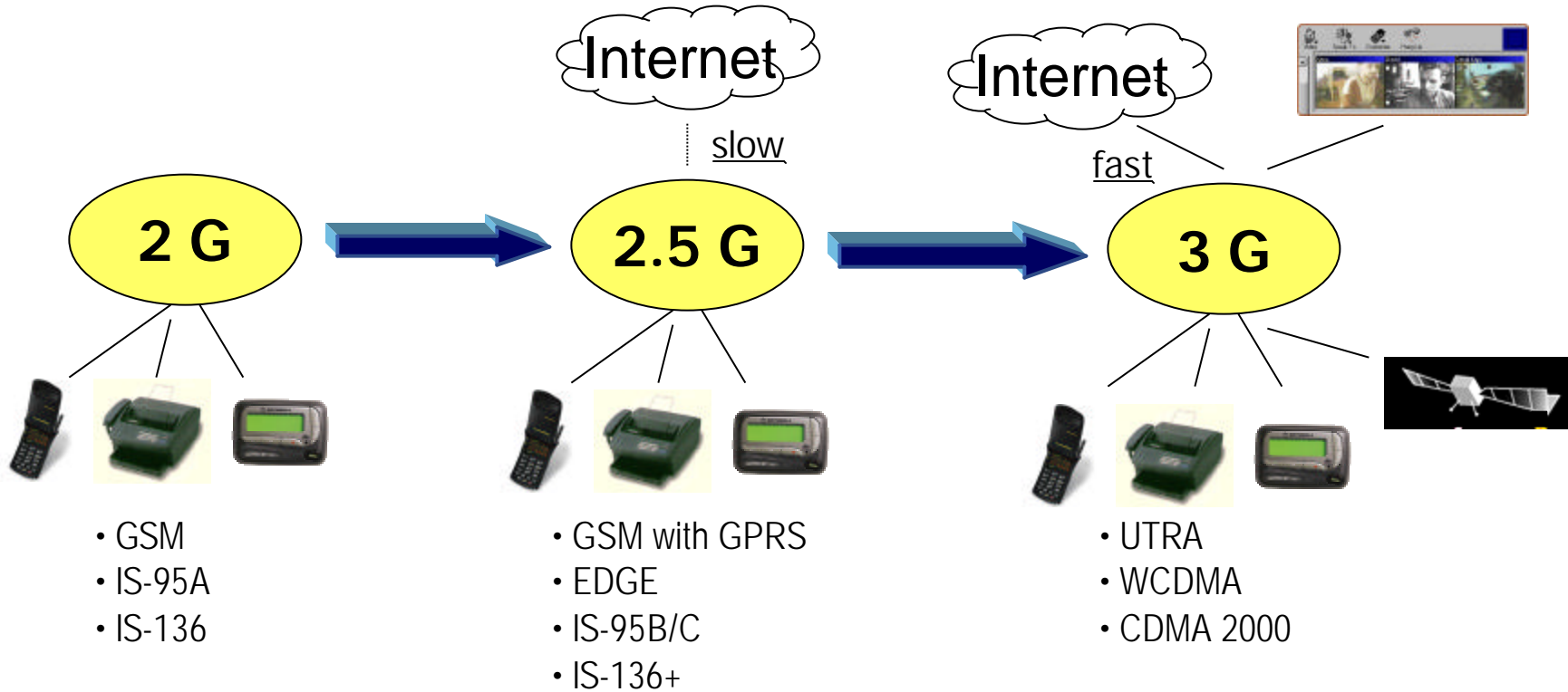
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- 1890's - Marconi's first radio transmission
- 1920's - First pagers (non-commercial use)
- 1940's - AT&T Mobile Telephone Service
- 1960's - Improved MTS
- 1970's - First generation cellular (e.g. AMPS)
- 1980's - Commercial-use pagers
- 1990's - Low to Medium-speed wireless data
  - CDPD (19 kbps), 2G digital cellular (9.6 kbps), 1G wireless LAN (2-4 Mbps).
- 2000's - Medium to high-speed wireless data
  - 2.5G digital cellular (< 384 kbps), 3G digital cellular (< 2 Mbps), 2G wireless LAN (10-155 Mbps), Bluetooth 2 (10-20 Mbps), HomeRF (10-20 Mbps), Wireless Cable (10-100 Mbps).

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# Driving Force Behind 3<sup>rd</sup> Generation Wireless Systems

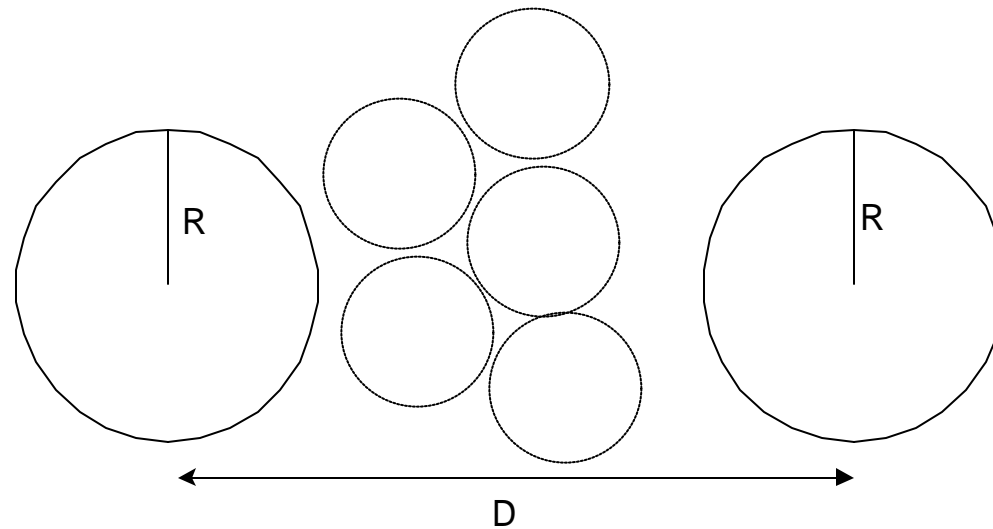
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- New media: video and image
- **High-speed Internet access**

# Interference & Capacity

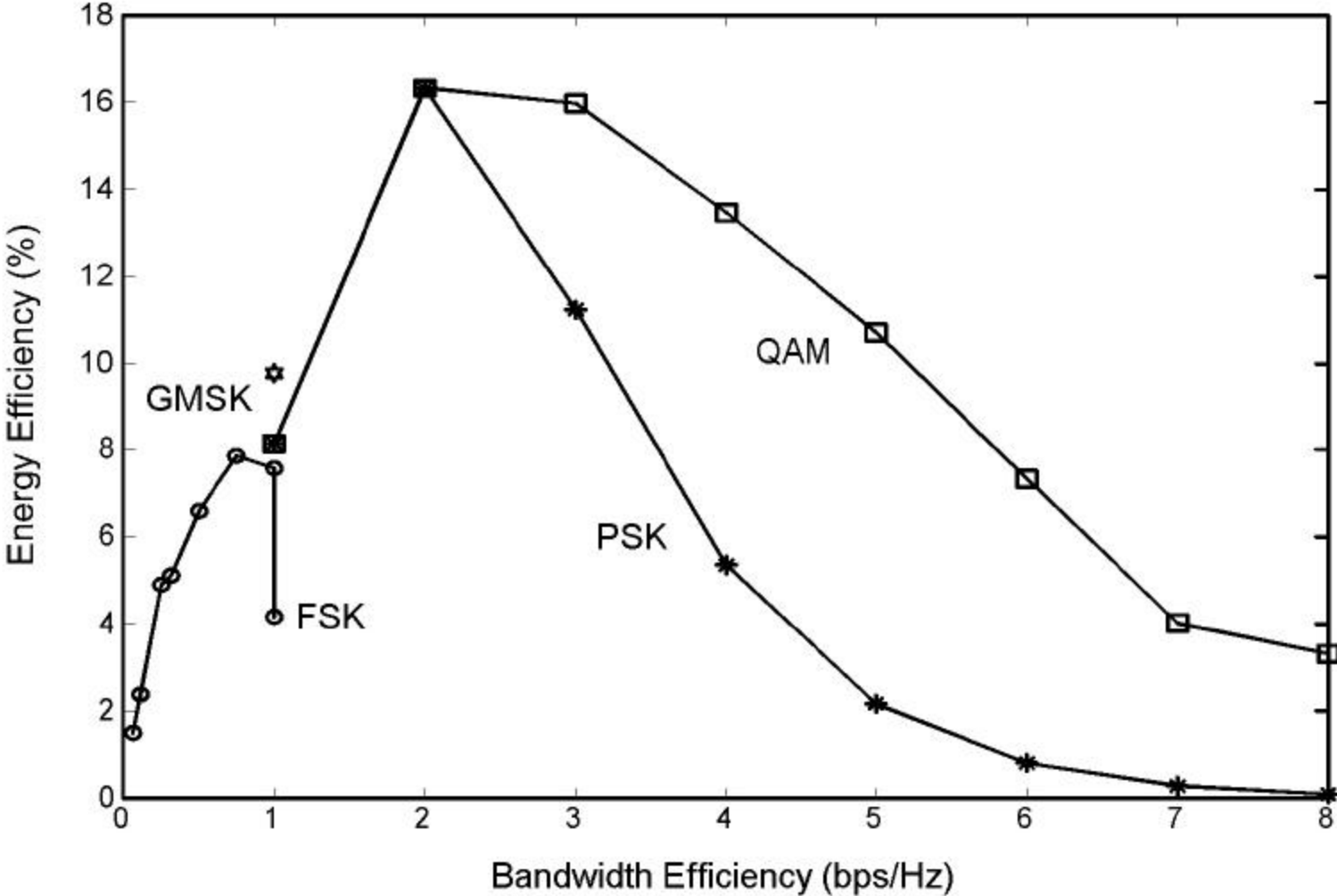
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- Number of cells within the re-use distance is usually 3-4 for current digital cellular systems.
- Capacity reduced by 3-4.
- CDMA claims 1 cell per re-use distance.
- Problem becomes severe in unlicensed bands and shared bands.
  - Bluetooth
  - WLAN
  - HomeRF
- System must adapt to interference.

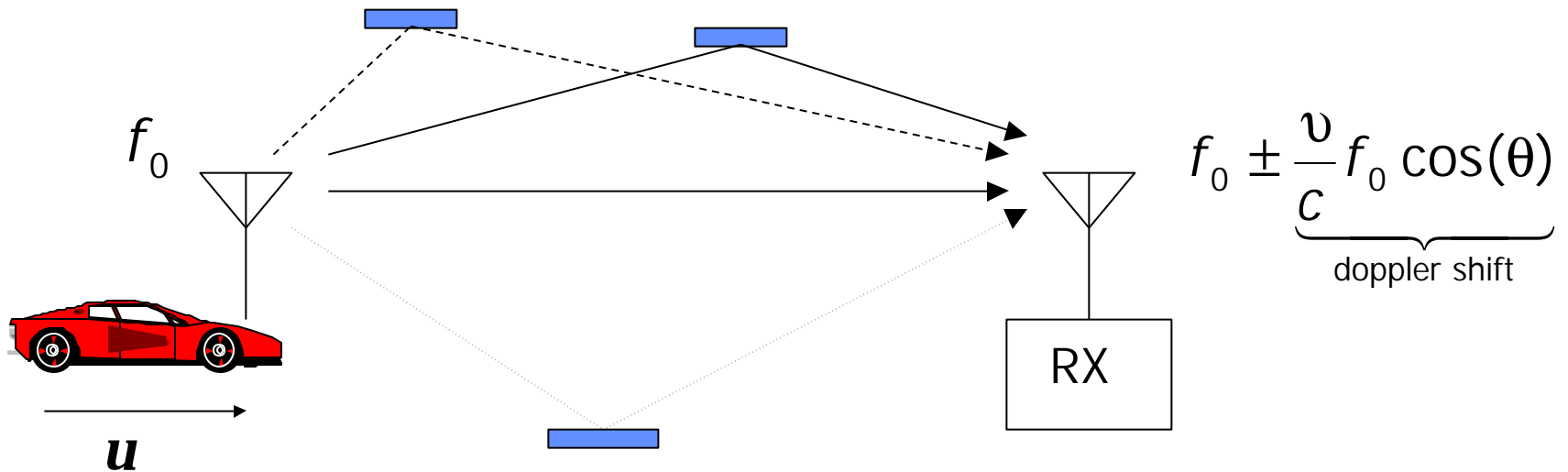
# Bandwidth and Energy Efficiency

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# Multipath Fading

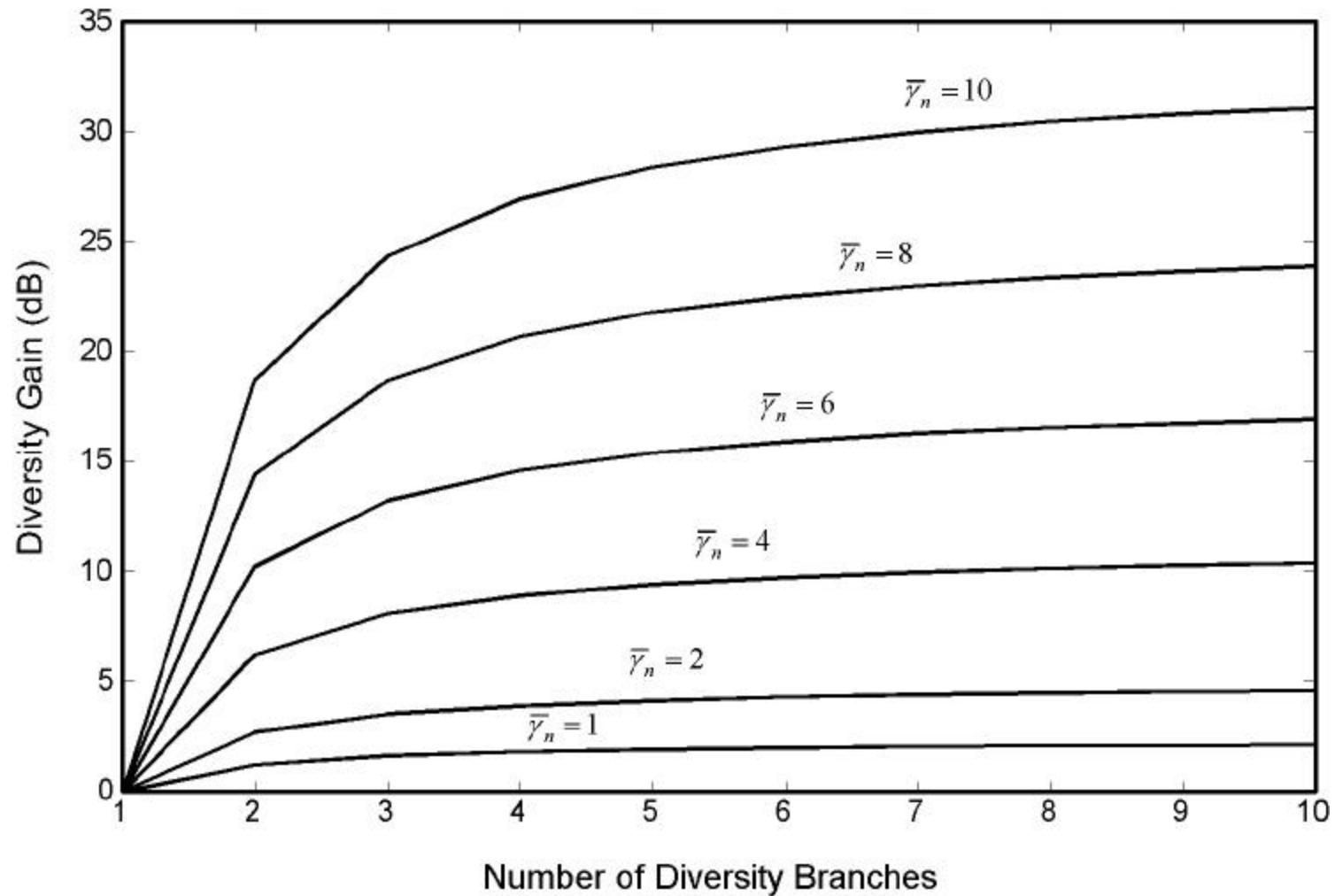
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# Diversity Gain

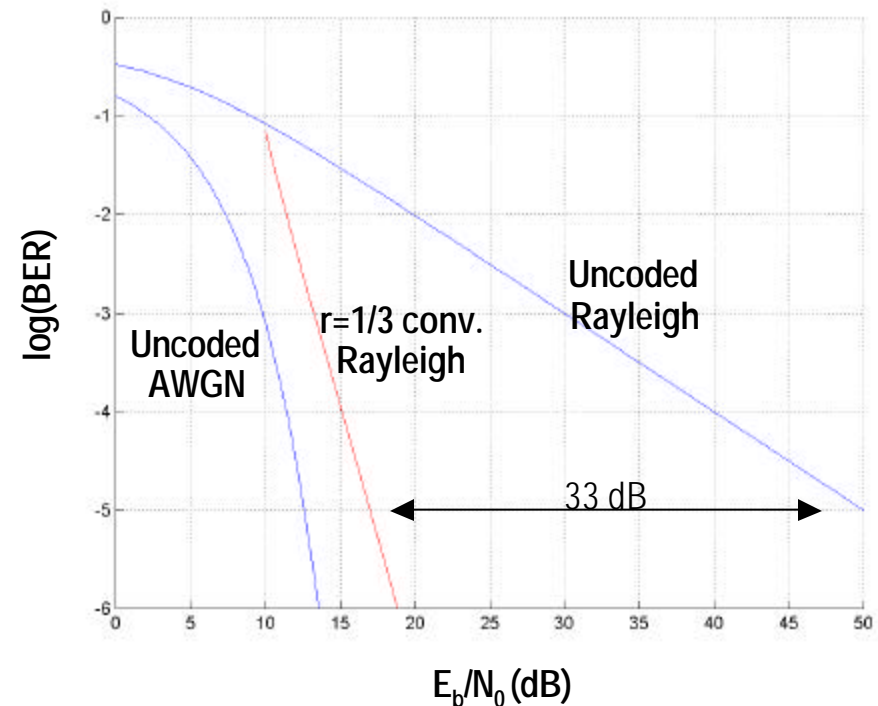
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# Means to Obtain Diversity Gain

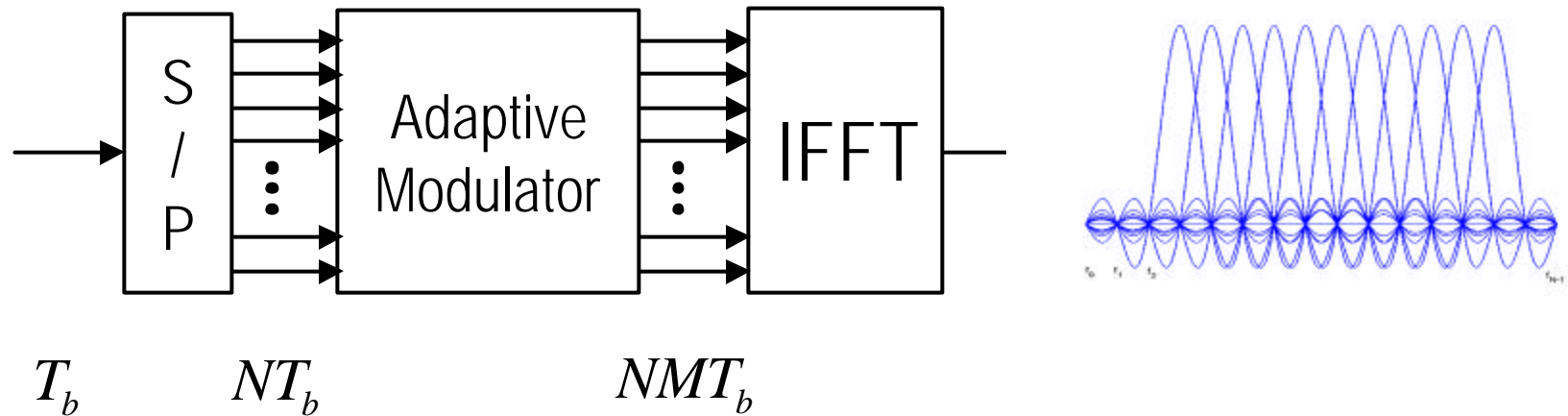
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- Error coding/Interleaving
  - Convolutional (rate 1/2)
  - Reed Solomon
  - Concatenated coding
  - Turbo codes
- Equalization
  - TDMA: MLSE
  - CDMA: Rake
- Space-time Processing
  - BLAST
  - VOFDM



# Orthogonal Frequency Division Multiplexing (OFDM)

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- Robust to multipath fading.
- Adaptable to interference and varying channel conditions.
- Enables systems that are spectrally efficient.

# OFDM Design Challenges

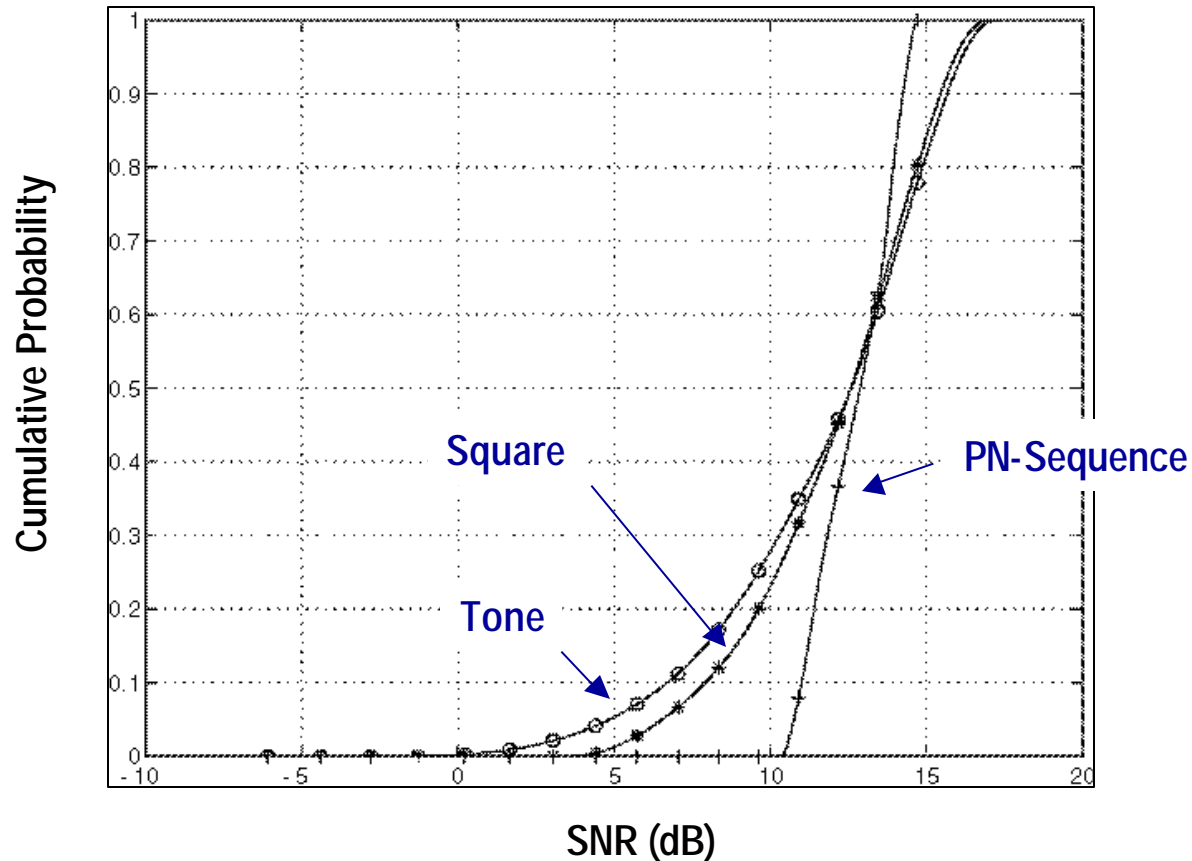
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- High peak-to-average ratio (6-12 dB)
  - Complementary coding: reduces phases adding up coherently.
  - Cluster OFDM: reduces number of sub-channels per antenna.
- Sensitive to frequency offset (< 1% of channel spacing)
  - Brute force: use 0.1 ppm oscillators.
  - Robust estimation: use PN-codes.
- Channel estimation (< 1-5 % RMS error)
  - Interpolation: in time and/or frequency
- High-speed, complex signal processing (10 GOPS with 1  $\mu$ s delay spread at 1 Gbps, 10X existing FFT chips.)
  - Efficient architecture implementation.

# Robust Frequency Estimation (Exponential CIR)

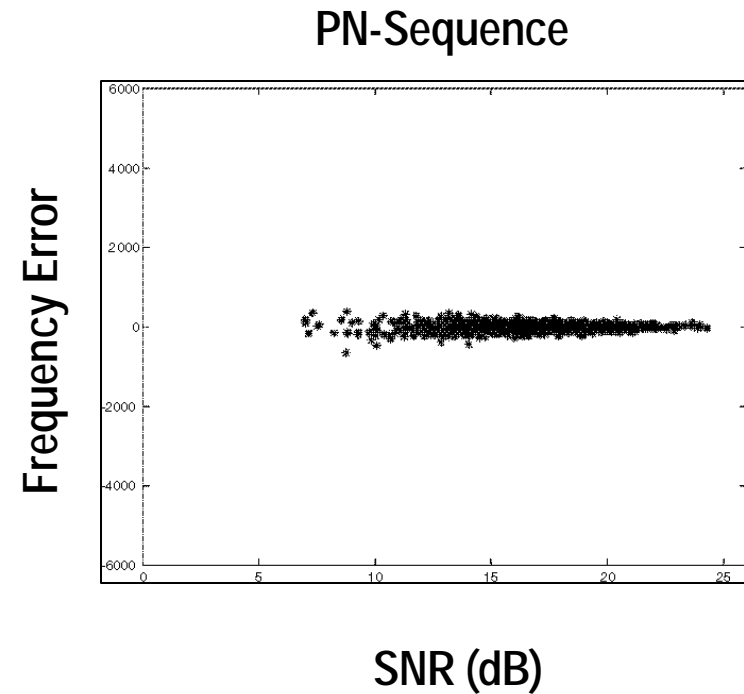
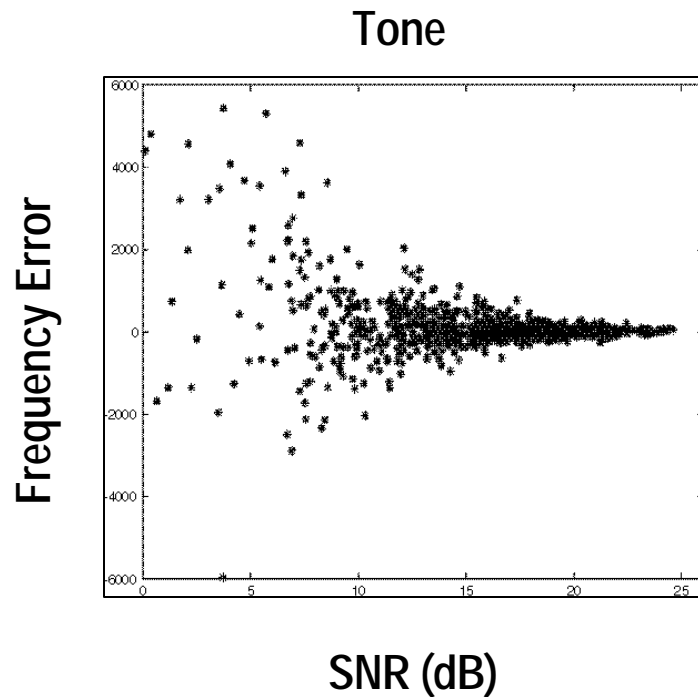
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- EXP with [0 dB, -3 dB, -6 dB, -9 dB, -12 dB]
- Assumes uniform phase, Rayleigh amplitude distribution, and a delay spread of 5 msec.

# Robust Frequency Estimation (GSM TU Channel)

File Name-9/14/00-14



- GSM TU channel
- 128 bits preamble size.
- Tone preamble shows a 4000 Hz error spread.
- M-sequence preamble shows a 300 Hz error spread  
=> sub-channel spacing could be as narrow as 30 kHz

# OFDM Systems

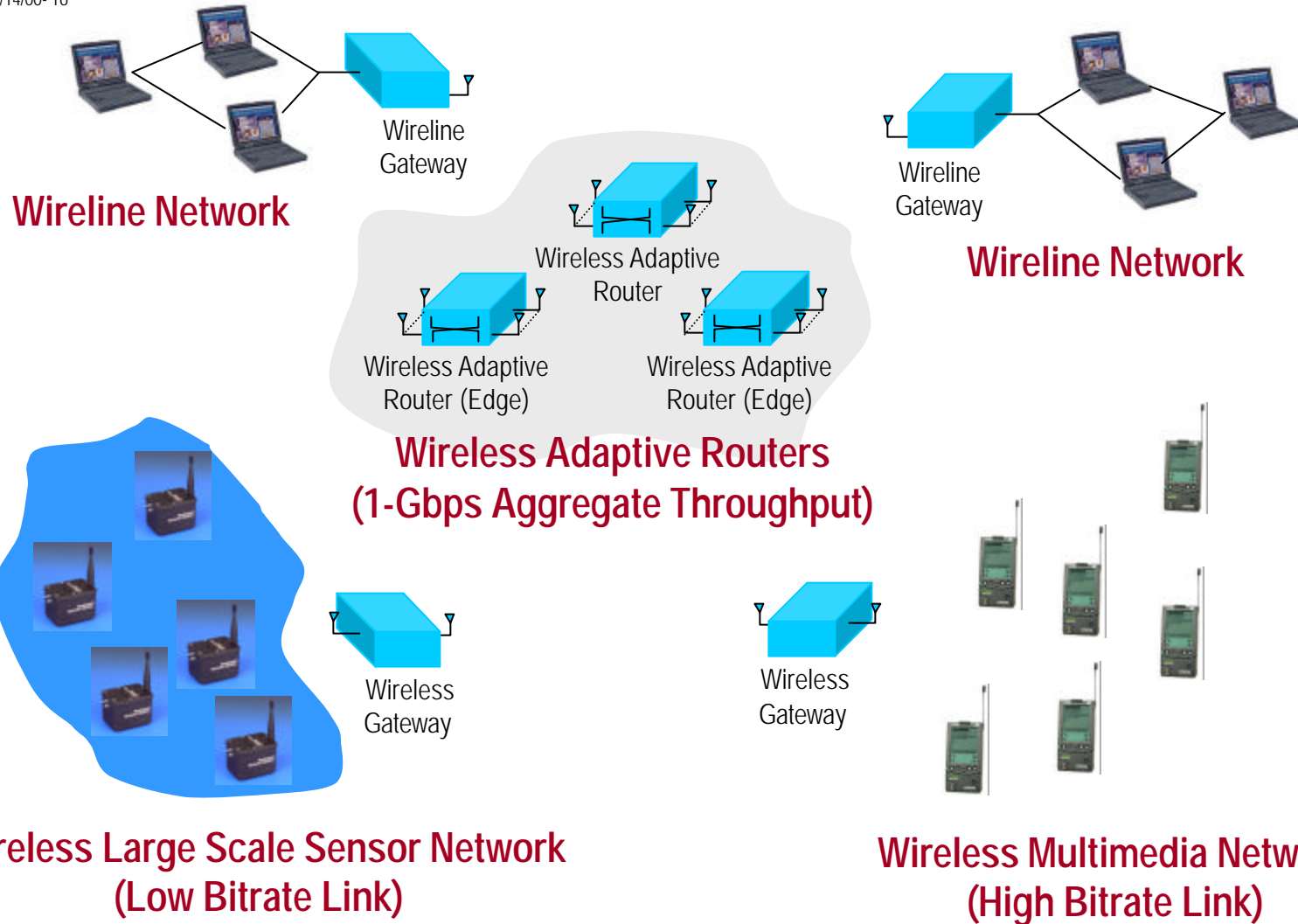
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- Asymmetric digital subscriber lines
- Digital audio broadcast
- Digital television broadcast
- Second generation wireless local area networks
  - IEEE 802.11a - up to 54 Mbps
  - HiperLAN
- Wireless fixed access: VPN, internet access, ...
  - VOFDM - up to 44 Mbps
  - AT&T digital broadband fixed wireless network
- Mobile distributed all-IP network
  - Flash OFDM

# Gigabit Wireless Router Broadband Wireless Backbone for NG Internet

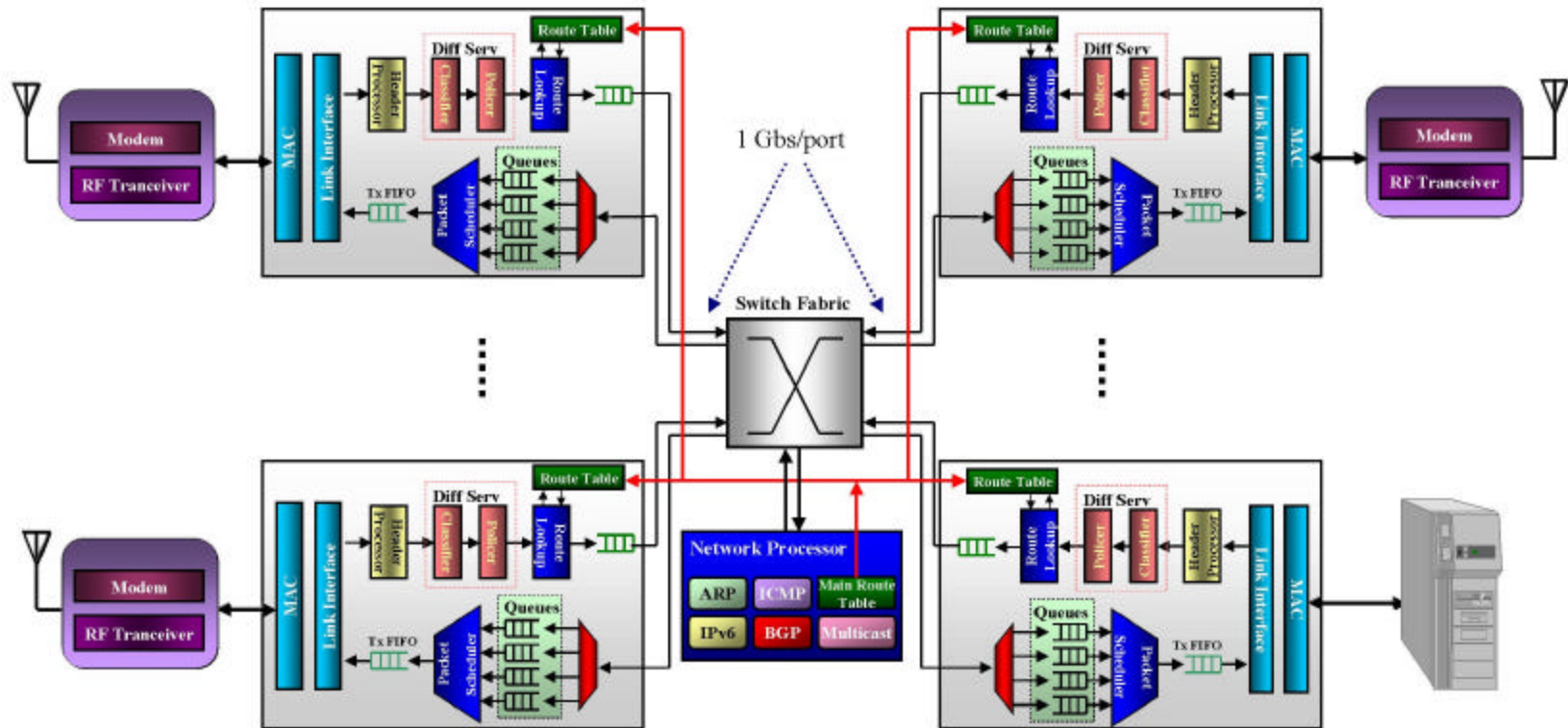
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# Gigabit Wireless Router Architecture

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## Features:

- **Broadband** wireless communications: Max. 1 Gigabit/sec per port.
- Adaptive channel loading for **robust** 1-Gbps transmission over potentially hostile environment.
- Dynamic subchannel and frequency band allocation for **high spectral efficiency**.
- **Adaptive system architecture** to achieve QoS with 1-Gbps aggregate throughput



# Conclusion

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- Extremely low data rate (< 1 kbps): 1890 - 1980's
- Low to medium data rate (<4 Mbps): 1990's
- Medium to high data rate (up to 1 Gbps): 21<sup>st</sup> century
- Internet connections will exceed the world population by 2005.
- New high speed data services
  - wireless fixed access inter-residential and businesses
  - high-resolution real-time multimedia
  - high speed internet access: e.g. pervasive (Connexion by Boeing).
- Challenges:
  - High speed ADC/DAC - 1-10 GSps
  - Broadband front-ends
  - PA linearization
  - High-speed digital processing
  - Optimized system architecture to effectively manage radio resource for high spectral efficiency and QoS

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