Multimedia Over 5 GHz Wireless Home Networks

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Multimedia Streaming Across Home Networks

P316

Topics

- The Connected Home
- Wireless Multimedia Requirements
- QoS – What does it mean in a wireless network?
- System Design for Multimedia Wireless
- Real World Test Results

The Connected Home Era

- Convergence of new technologies
  - New entertainment models (e.g. on-demand)
  - New TV form factors (PDP, Portable LCD)
  - Online multiplayer video games
- Leading Consumer Electronics Companies and Service Providers strategically positioning themselves for the Connected Home Era by enabling rich entertainment experiences

Multimedia Segment

DATA
Broadband Data Sharing
PC LAN
Information Devices

HOME MANAGEMENT
Home Controls
Energy Management
Safety/Security
Remote Apps

MULTIMEDIA
Gaming
Personalized Content
Stored/Streamed AV
On-demand Content

VALUE-ADDED SERVICES
Voice
Protection
Upgrades
Communities

Home Network providing rich entertainment experiences

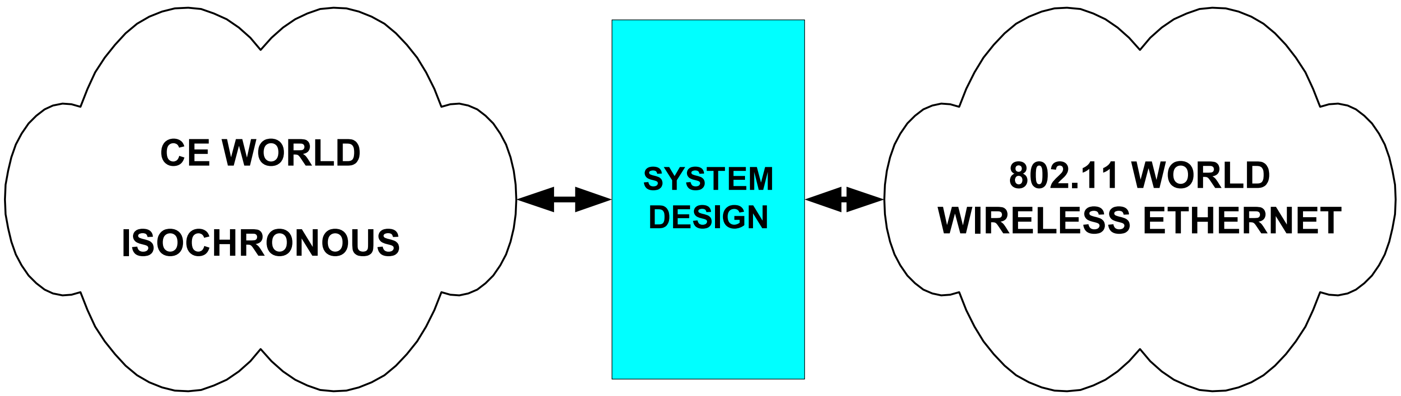
Multimedia vs. Data

- Companies have attempted to build multimedia networks based on computer communication protocols (e.g. 802.11x). The drawbacks are:
  - These systems were based on protocols designed for connecting computers over a noise-free medium (i.e. Ethernet)
  - Host computer or processors with operating systems must always be present
  - MPEG-2 content must be encapsulated into TCP/IP packets and be passed through an asynchronous network stack
  - Streaming/ "pull technologies" must be used, resulting in large buffering delays and intermittent loss of signal.

What Multimedia Needs

- The requirements of a true multimedia networking technology take the following into account:
  - Interfaces designed to connect directly to A/V equipment and PCs
  - Ability to operate without a host PC or operating system
  - Provisions for dual data and isochronous interfaces, capable of simultaneous operation
  - Direct MPEG-2 interfaces with built-in synchronization between source and destination to remove latencies and signal loss conditions. This allows for the delivery of “live” video.

Asynch vs Isoch World



System Design is needed to bridge from CE to Ethernet space for those who want to try it …

Video Delivery Systems– Three Ways To Go

- Stay Isochronous
  - e.g. Magis Air5, 1394
- Use Glue System Chips
  - e.g. Transcoders
- Implement Glue Systems
  - e.g. 802.11x plus $$$ in Buffers, Bridge Chips, etc.

There is NO standards-based solution to deliver wireless video!

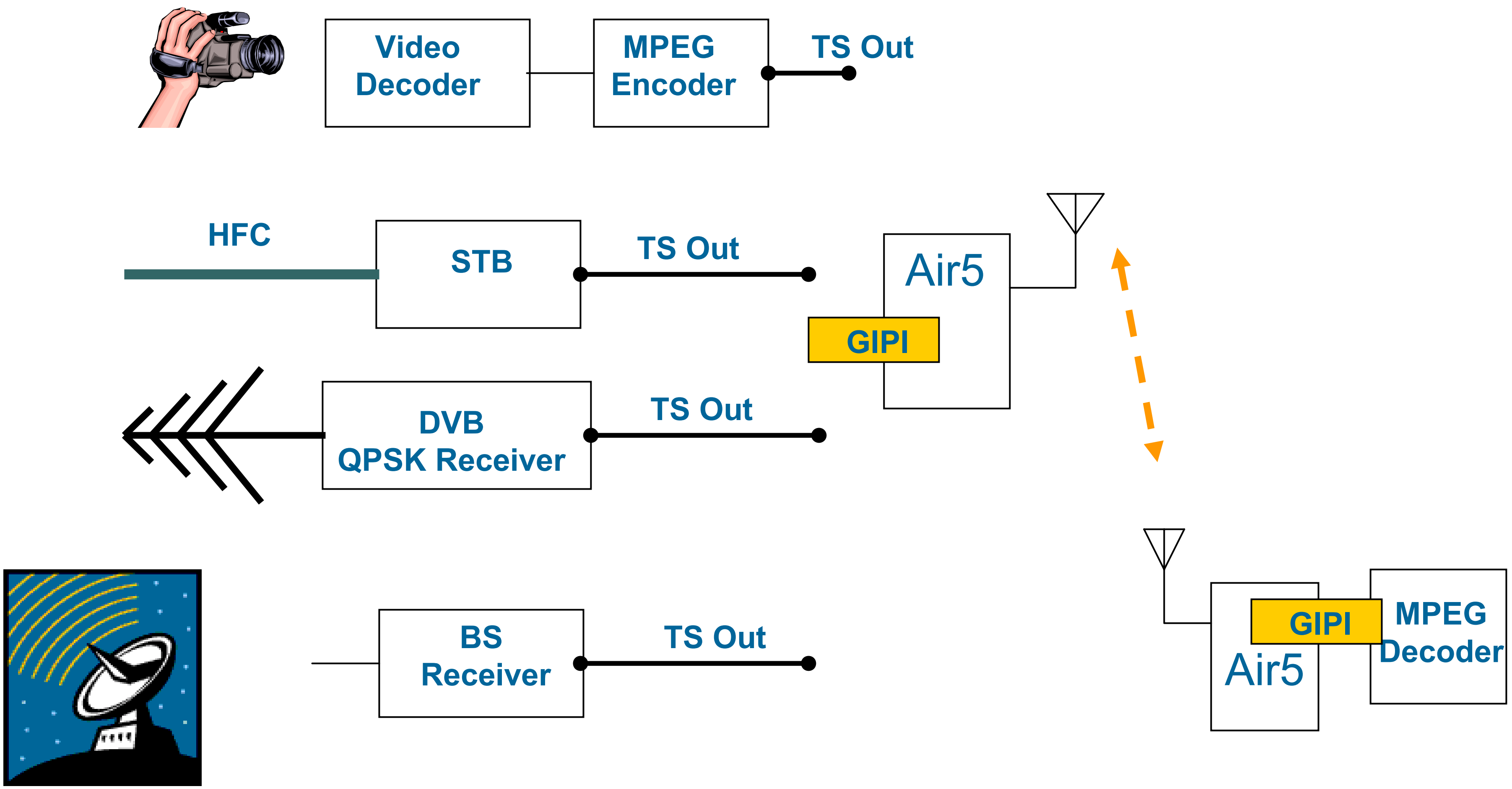
QoS In Wireless Networks

- Latency and jitter requirements of A/V systems pose a significant design goal to any network carrying this content, especially a wireless one!
- Synchronous networks can achieve these requirements given that they are designed with the proper constraints and attention to the key latency, jitter, and PER performance parameters.

Typical QoS Requirements

Input Parameters of Performance Testing			Output Parameters of Performance Testing			
Service	**Number of Streams**	**MAC Payload Rate (per stream)**	**Packet Size (bytes)**	**Max PER**	**Max Latency**	**Max Jitter**
Multiple Stream (1 HDTV/2SDTV)	3	35 Mbps	228	**3.6* 10-5**	90ms	+/-10ms
US- HDTV	1	19.68 Mbps	228	**3.6* 10-5**	90ms	+/-10ms
SDTV/DVD	1	3-8 Mbps	228	**3.6* 10-5**	90ms	+/-10ms
HQ Video Conf. Call	2 per call	1.5 Mbps	228	**3.6* 10-5**	10ms	+/-5ms
CD Quality Audio	1	256 kbps	360	**5.8* 10-5**	100ms	+/-10ms

Architecture: MPEG TS Systems



Video Synchronization Problem

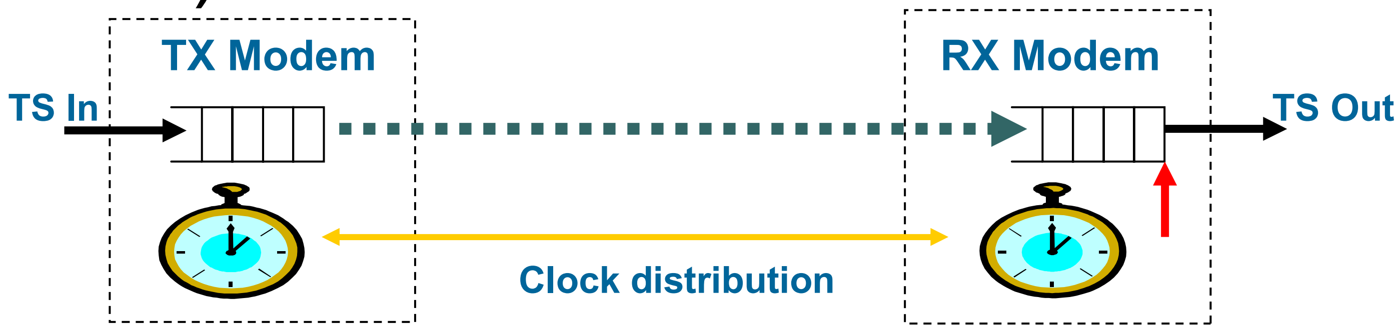
- MPEG-2 is transported over two formats
  - Program Stream is designed for use in relatively error-free environments. Can be variable and of great length.

    Example: DVD
  - Transport Stream is used when video is to be rendered immediately (live, real-time programming).

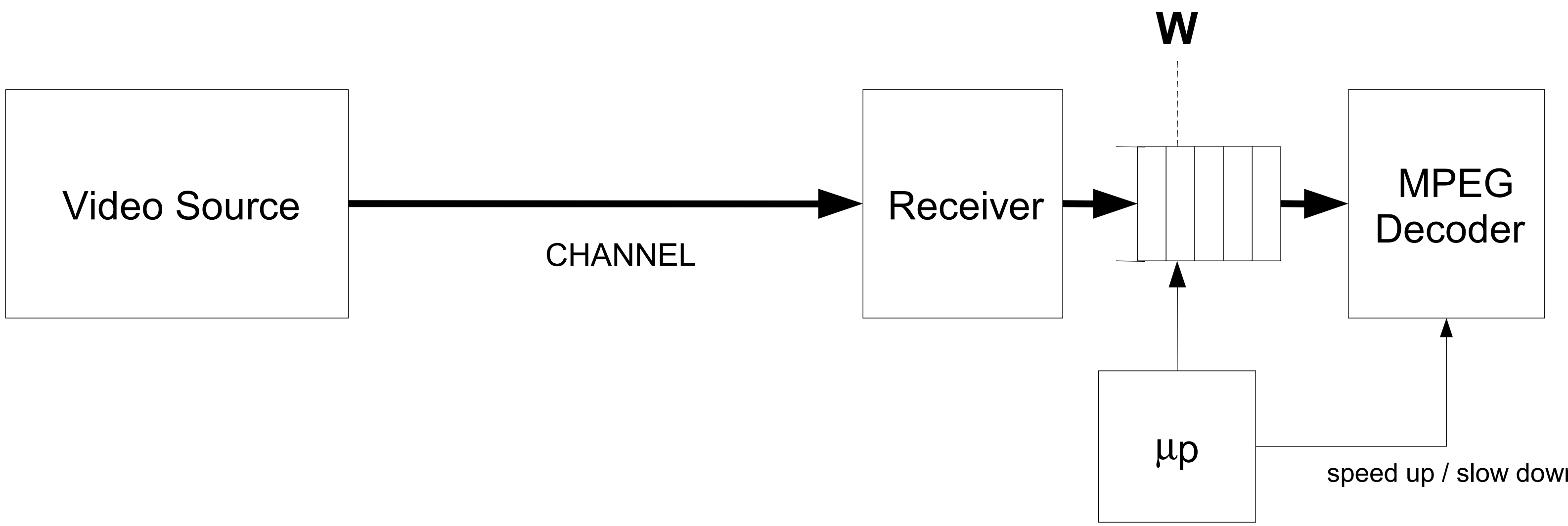
    Example: Cable, Satellite

Inter-Packet Time Preservation

- Communication systems like 1394 and Magis' Air5 perform this inter-packet spacing preservation – critical for delivery of real-time MPEG.
- 802.11x systems do not, and require external buffer management (extra HW and SW).



Buffer Mgt Req'ts of 802.11x



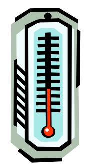
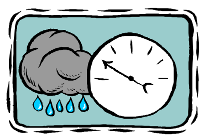
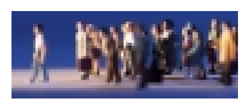
- uP observes watermark "W" and adjusts clock based on buffer size.
- Large buffer needed for channel losses
- Results in time delays to end user
- Over long term buffer underflow or overflow can occur
- Experience like streaming video ("*buffering …* ")

Example: Air5 Inter-Packet Time Preservation

- Direct connection to MPEG encoder / decoder chipsets
- Time of arrival is determined and forwarded to receiving end internal to MAC.
- <u>No</u> expensive off-chip memory for system buffering is required!
- No system software or host processor required for buffer management!
- Less than 8 mSec of latency.

RF/Phy/Mac Design For The Indoor Wireless Channel

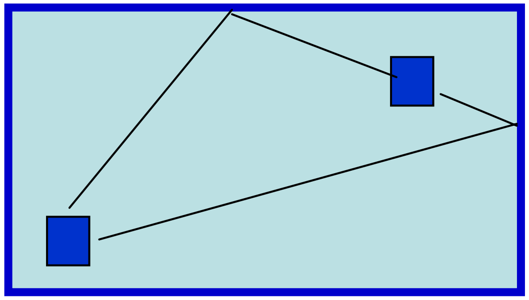
Indoor Wireless Channel

- Very difficult to model accurately
- Everything matters:
  - Temperature 
  - Humidity 
  - Presence of People 

- Quarter-wavelength at 5 GHz is only about 1.5 cm

Indoor Channel Multipath

- Multipath reflections occur from all materials larger than ~ 1.5 cm
- Any material that exhibits a characteristic impedance different than free-space (277 Ohms) can contribute reflections
  - Non-conductors: Glass, Carpet, Wood
  - Conductors: Metal



Indoor Channel Multipath Modeling

- Most modeling efforts use a power-law model for range dependence that is very idealized:
  - CW source
  - Many points taken within say a 1 meter radius
  - One antenna polarization at transmit and receive ends
  - Heavy spatial averaging to achieve meaningful results

Indoor Channel Multipath Modeling

- Simple power-law methods do not capture the true picture
  - Coherence bandwidth issues not included
  - Spatial averaging conceals the benefits possible with multiple-antenna solutions
  - Severe fading can often extend across the entire modulation bandwidth and last minutes
- Multiple-Input-Multiple-Output (MIMO) perspective more applicable to understanding the true wireless channel…but complicated.

Achieving Video-Quality QoS

- MPEG2 QoS levels impose requirements on both the PHY and MAC layers
  - Adding a synchronous MAC to an otherwise 802.11a PHY only addresses one portion of the problem
- Video-quality QoS requires:
  - Isochronous MAC to provide time-bounded access to channel timeslots
  - Highly reliable PHY that reduces outage probability levels far below single-antenna 802.11a systems
    - …because indoor channel outages can last many many seconds

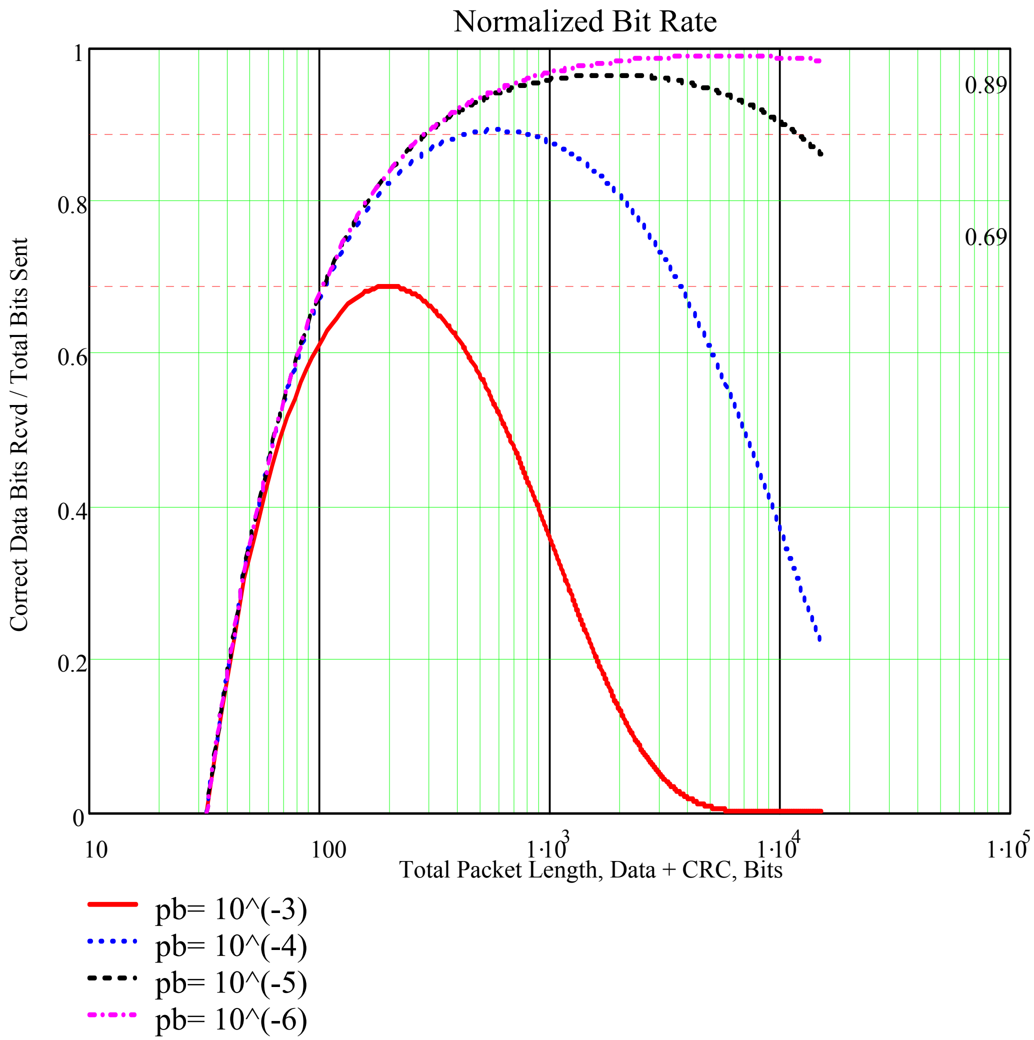
MAC/PHY Co-Design is Crucial

- OFDM system design issues well known
  - Low symbol rate presses phase noise requirements
  - Peak-to-Average Power Ratio (PAPR) of OFDM leads to challenging linearity needs
  - Direct-conversion architectures very challenging due to OFDM's frequency bin-by-bin structure

MAC/PHY Co-Design is Crucial

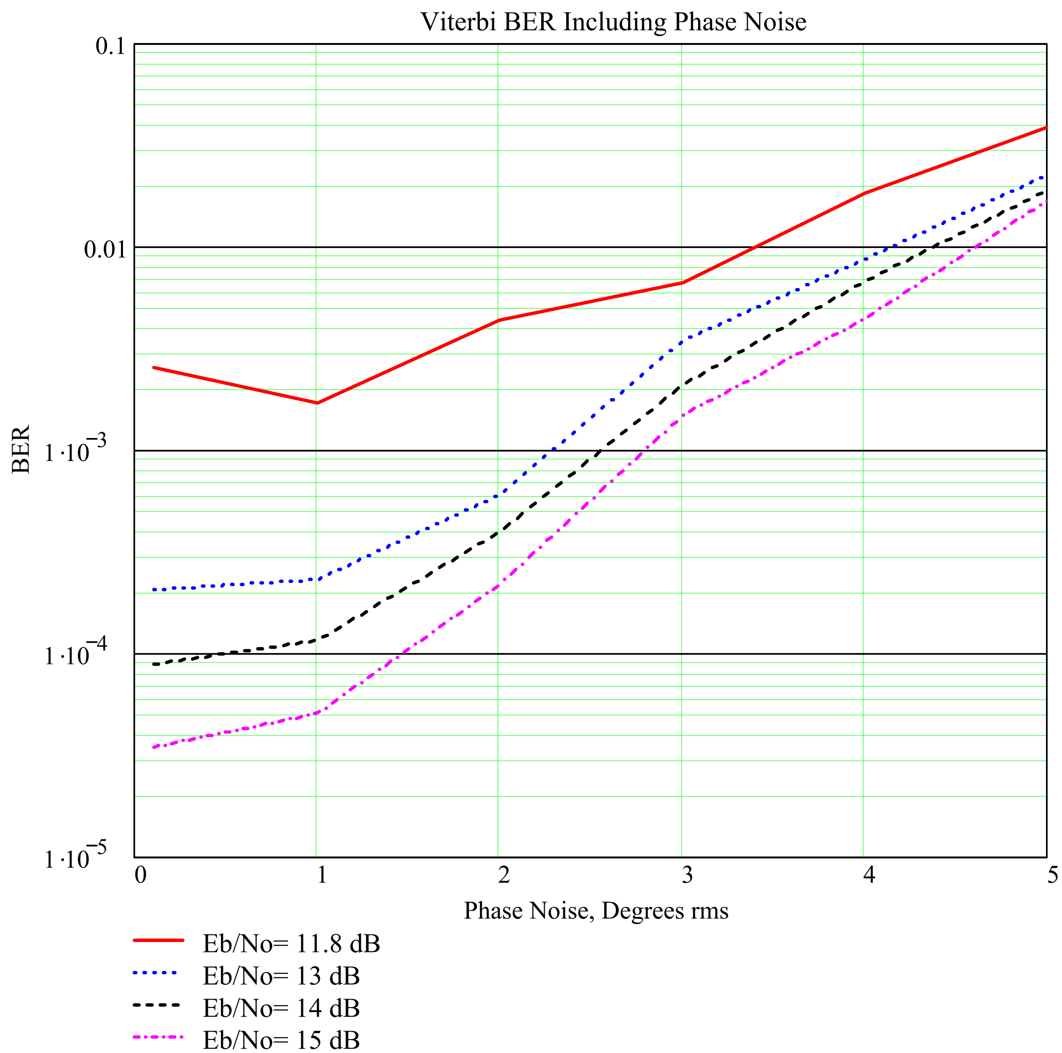
- Multipath channel imposes additional design constraints
  - Receiver linearity budget must include margin for potentially deep frequency fades
  - Channel can be slowly-changing, or quickly changing leading to AGC issues
- Typical data packet lengths used by 802.11 impose very demanding residual BER requirements on the radio.

MAC/PHY Co-Design is Crucial



Data packet length figures in prominently with payload throughput versus coded BER floor.

MAC/PHY Co-Design is Crucial



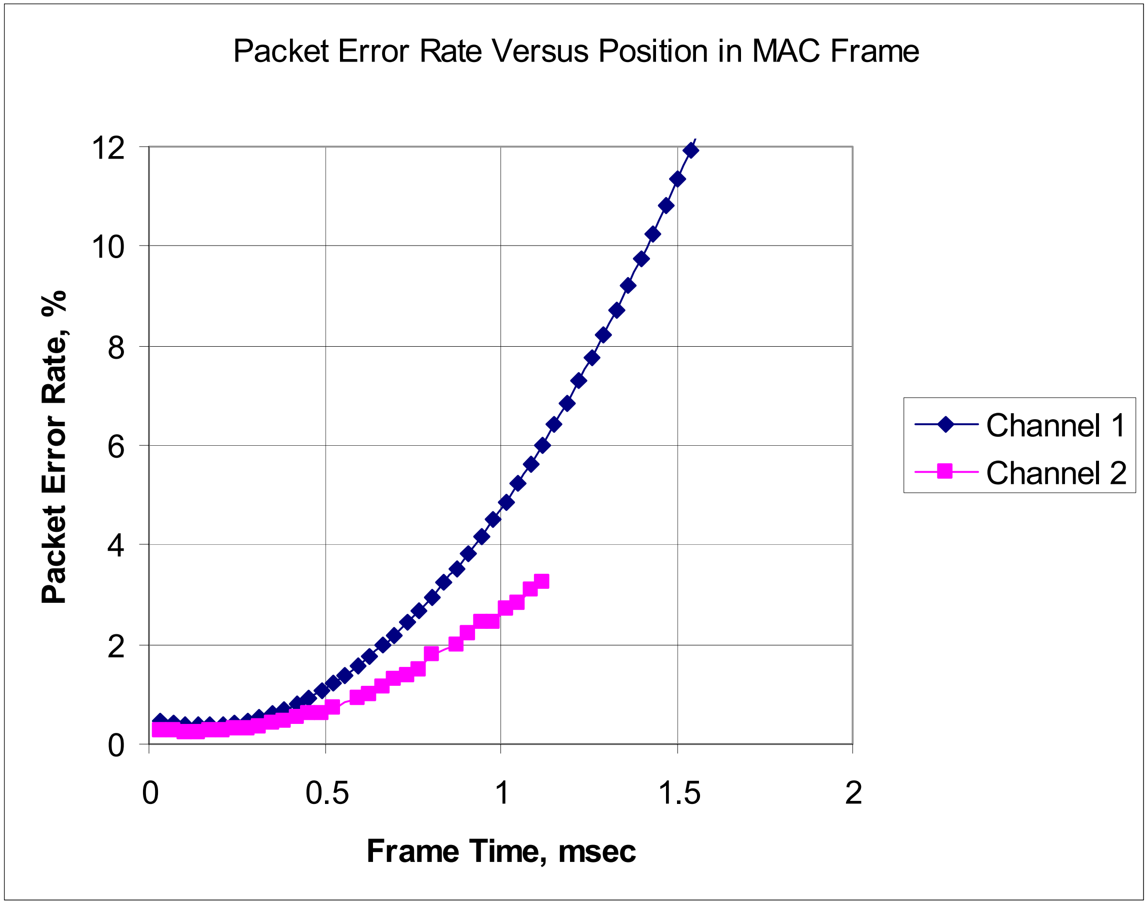
Phase noise alone dictates substantial residual error floor limits for 64-QAM R=3/4 mode.

Other imperfections including radio nonlinearities, quantization noise and channel impairments further impact the achievable error floor.

MAC/PHY Co-Design is Crucial

- Non-zero Packet Error Rate (PER) poses different issues for data versus video networks
  - Throughput must accommodate packet re-transmissions [e.g., 1/(1 + PER)]
  - Penalty for QoS links far worse
    - A 15% PER system that allows only 3 ARQ attempts to bound time-jitter will drop complete packets 0.34% of the time!
    - A lower PER is often not achievable in 64-QAM mode with typical 802.11 packet lengths

MAC/PHY Co-Design is Crucial



MAC frame length is driven by channel coherence time and signal processing choices*

*** See "Making OFDM Work for High-Performance Wireless Network Applications" at www.magisnetworks.com**

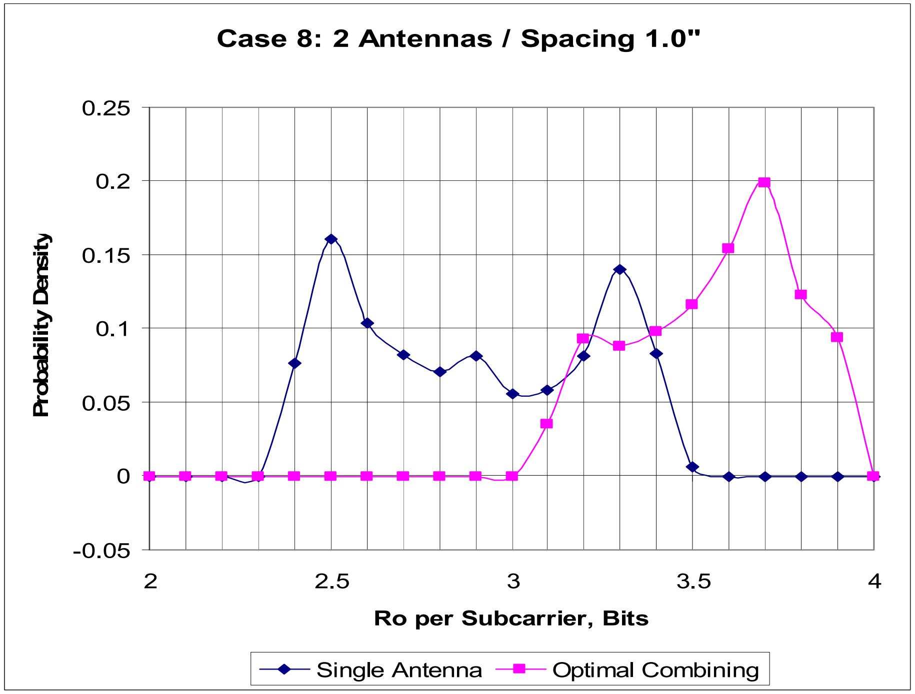
Multiple-Antenna System Design

- Joint space-time channel models can be used to improve system performance
- MIMO systems generally focus on obtaining higher throughput rates (more bits/Hz)
  - A non-zero outage probability is part of the package
  - Outage probability generally increases as throughput increases (compared to theoretical maximum)

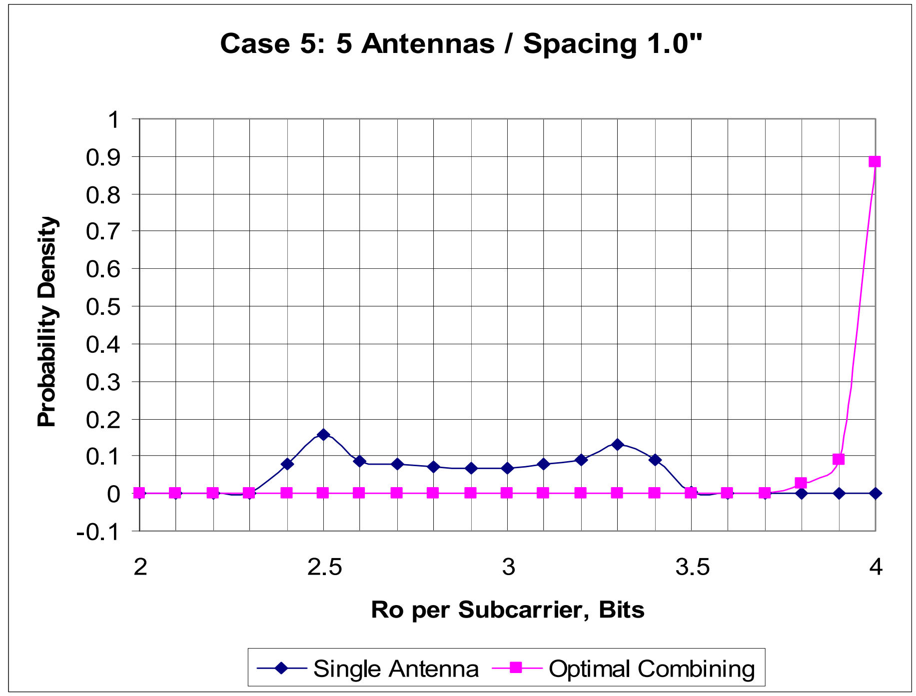
Multiple-Antenna System Design

- Alternative perspectives for use of additional channel dimensionality are possible
  - Use additional dimensionality to deliver exceptionally low outage probability at high “traditional” rates (e.g., 54 Mbps)
  - Untrue to think that high-rate MIMO systems with their residual outage probability can deliver good QoS for wireless entertainment
    - You can’t achieve both exceptional link reliability and maximum (MIMO) theoretical throughput simultaneously.

Multiple-Antenna System Design



Two-Antenna Case



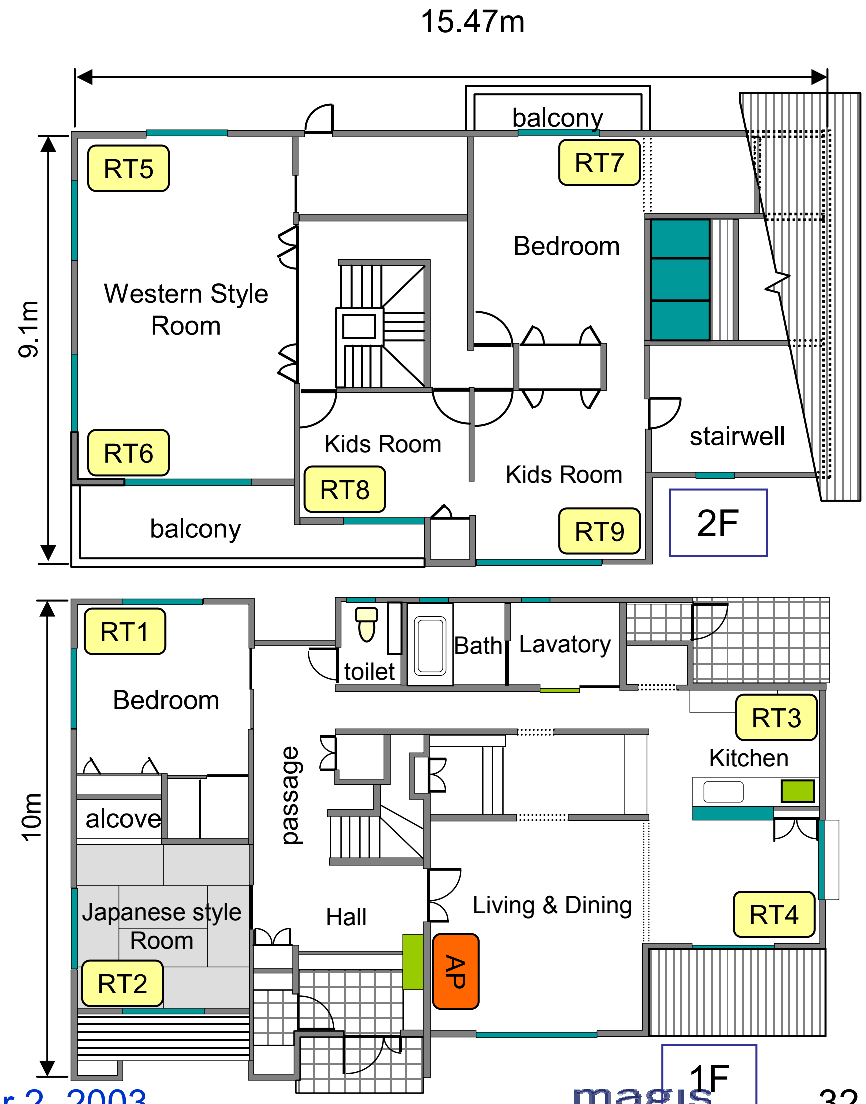
Five-Antenna Case

Cut-off rate analysis in text supports multiple antenna need for channel reliability.

Real World Test Results

- Magis Air5 has been tested in numerous large homes in both US, Japan
- Testing with MPEG video content
- No spatial averaging
- Throughput Result Criteria
  - Zero MPEG Packet Errors Received in multi-minute continuous span at sustained throughput

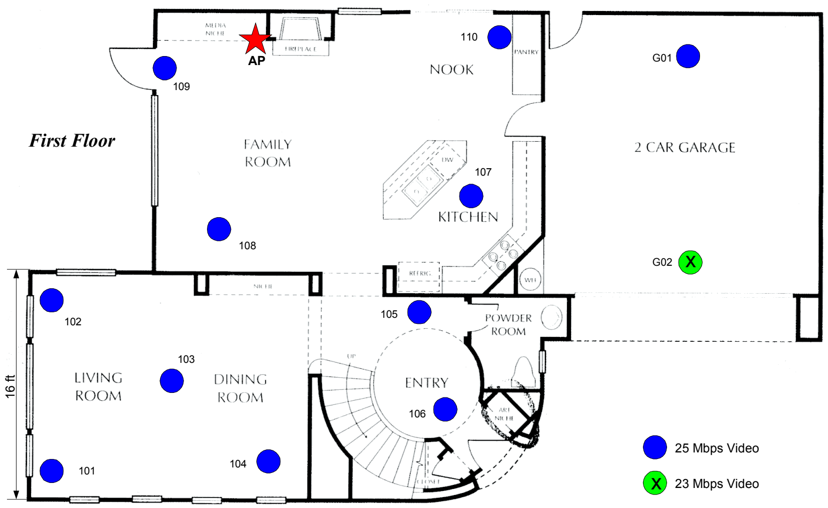
Japanese Home

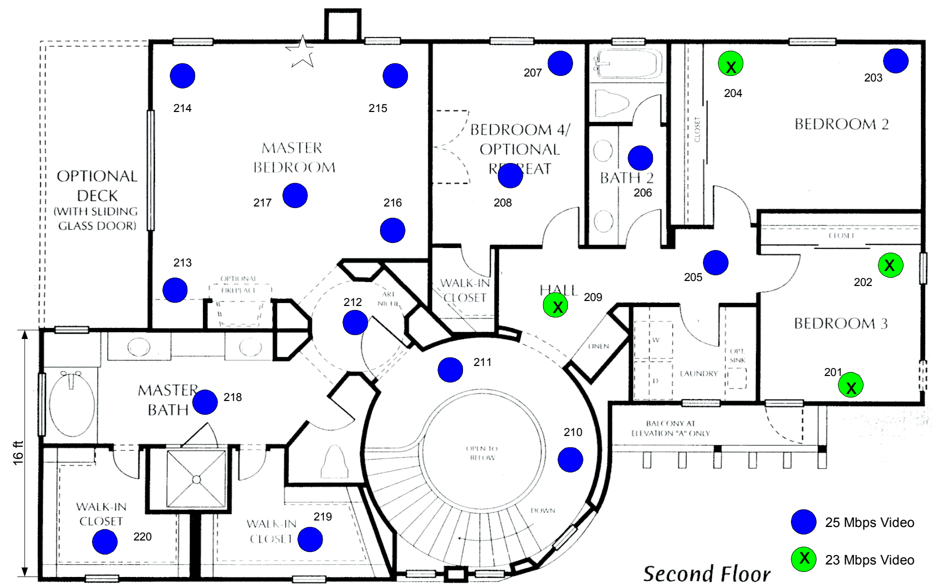


House test done in an atypically large 240 sq. meters, 2 story Japanese single family house in Osaka

Full home coverage at HDTV rates 28 Mbps and above.

US Home





The link coverage is remarkable in that a minimum of 23 Mbps is deliverable everywhere within the home, and only 19+ Mbps is required for US-HDTV

Summary

- True high-QoS requires a fundamentally different systems approach than traditional data-centric networking technologies
- Link reliability is equally as important as throughput rate
- Co-design of the MAC, PHY and RF is required in order to achieve the end performance and cost objectives