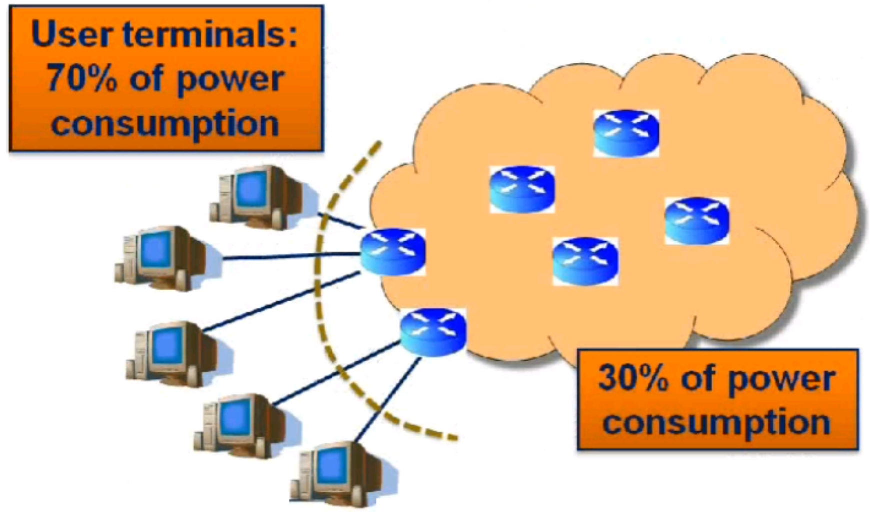
Efficient Power Allocation for Video Transmission over Superposition Coding

Basem Shihada

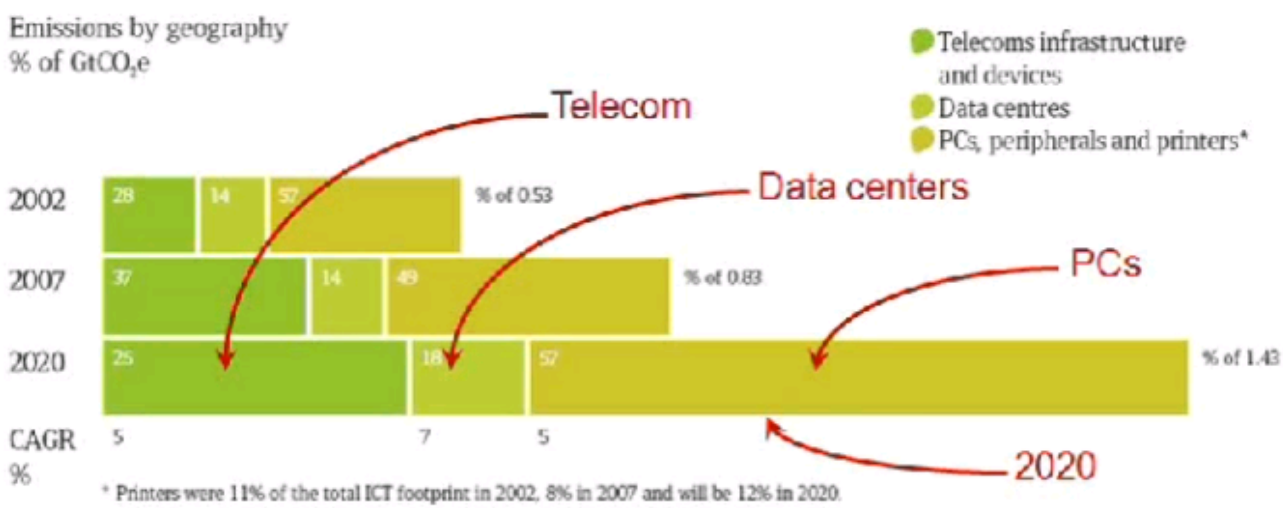
CEMSE, KAUST

ICT Energy Consumption

- Information and Communication Technology (ICT) alone consumes 2-10% of the world's generated power.
- ICT sector produces about 2-3% of the total emissions of greenhouse gases.
- Current figures are expected to double by 2020, with PCs being the major contributor!



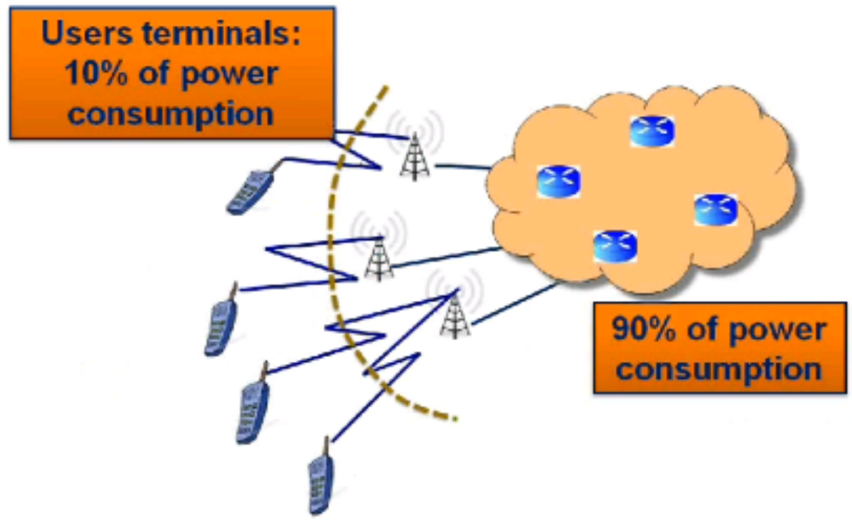
The global footprint by subsector



Energy in Wireless Networks

According to an estimate of Nokia Siemens Networks, worldwide…

Mobile WiMAX	LTE	HSPA
1280 W	1670 W	1670 W



3 billion x 0.1 W =
0.3GW

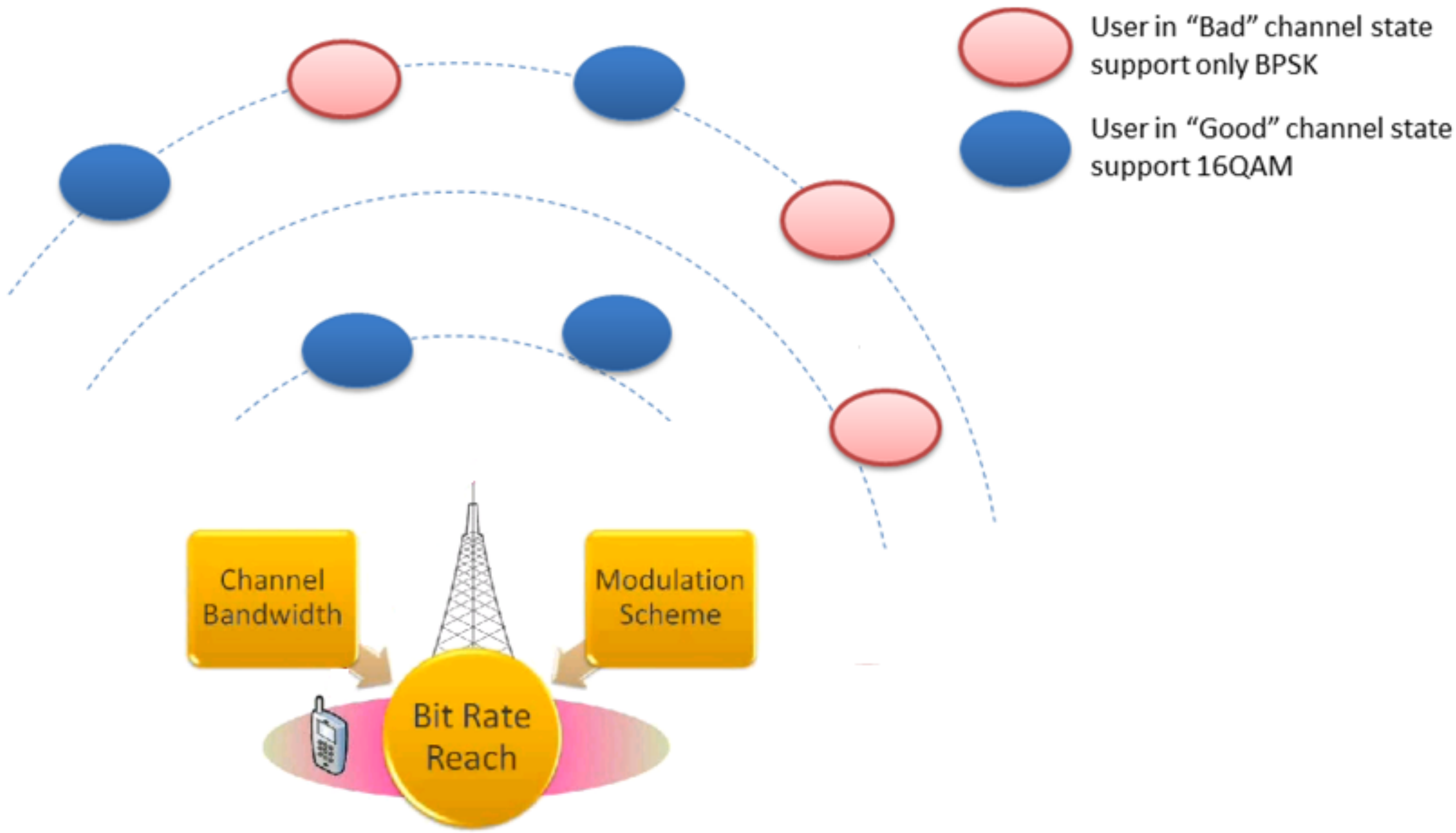
3 million x 1.5 kW =
4.5GW

10,000 x 10 kW =
0.1GW

About 10% of the energy drawn from the electric grid is converted to Radio Frequency

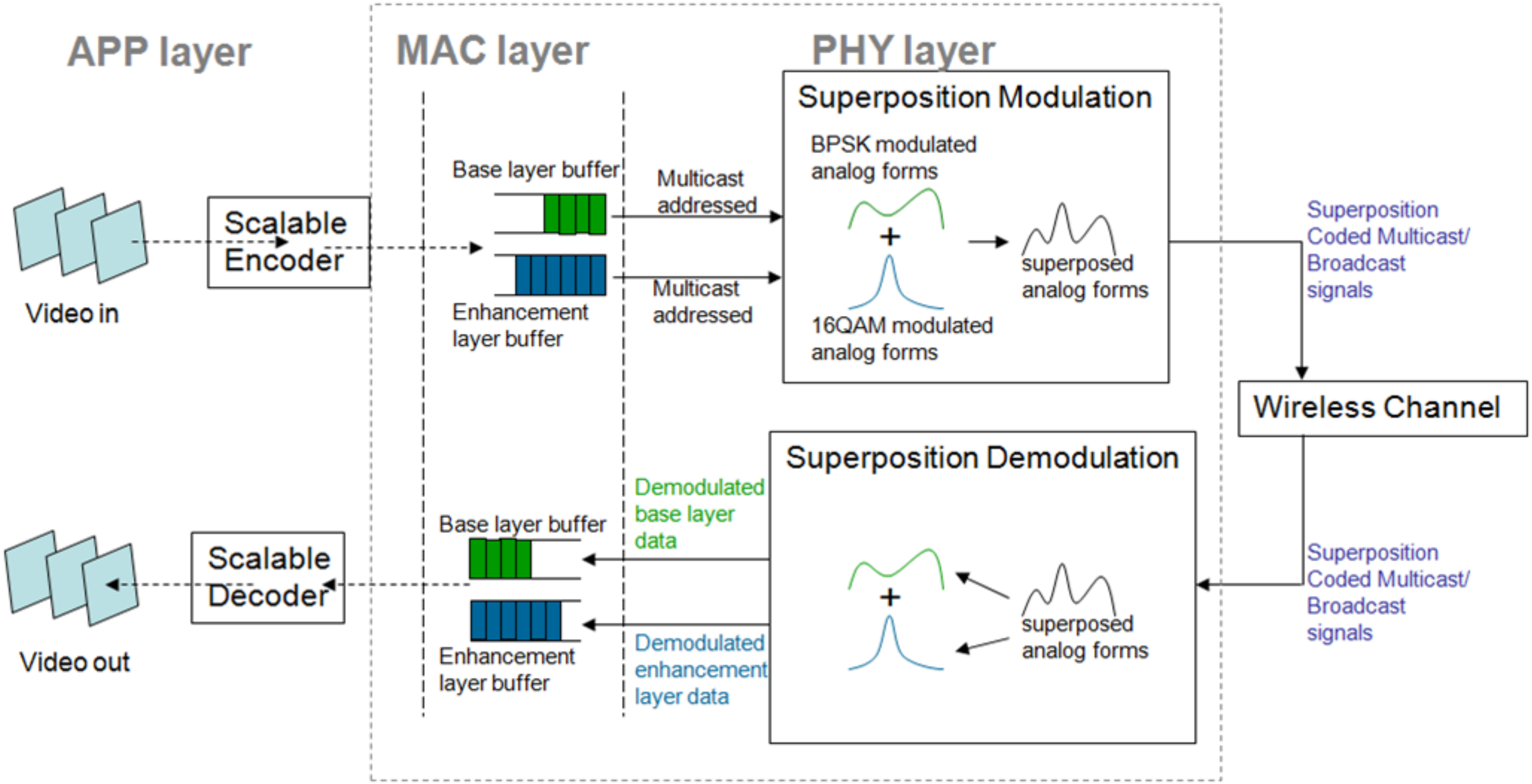
Mobile Operator Cost and User Satisfaction Tradeoff!!

Challenge! Multi-user Channel Diversity



How to select a proper transmission rate that satisfies all users at different wireless channel qualities?

Proposed Solution Framework



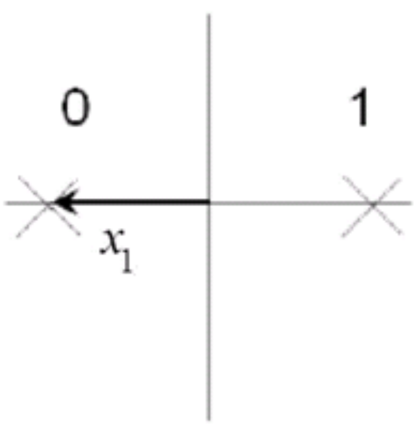
Superposition Coded Multicast (SCM)

Scalable Video Coding (SVC)

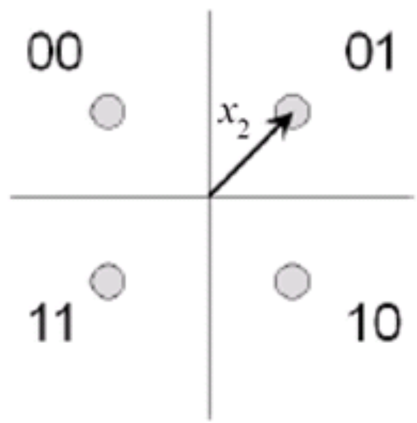
- Layered structure
- 1 x Base layer + n x enhancement layers
- Base layer
  - H.264/AVC compatible
  - Minimal information for video
  - Independent to enhancement layers
- Enhancement layers
  - Additional information for further improve video quality
  - Further enhance spatial resolution, temporal resolution and quality

Superposition Coding (SPC)

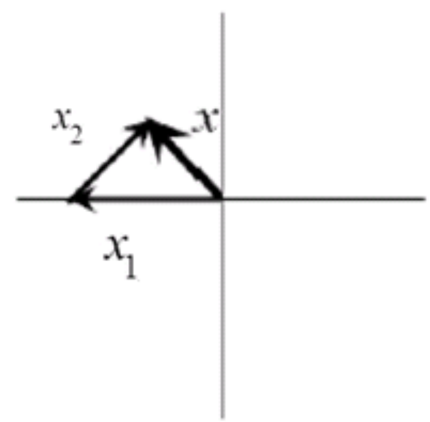
- Hardware circuitry at PHY Layer
- Send individual information to multiple receivers using a single wireless broadcast signal
- Multiple resolutions modulated symbol
- Vector addition of two signal constellations



BPSK



QPSK



SPC:BPSK+QPSK

Contribution

1. Examine the impact of power allocation of SPC signals on throughput performance[1]
2. Provide an empirical evaluation of SCM architecture[2]
3. Predict the video quality over different channel conditions[3]

[1] C. Lau, K. Jamshaid, B. Shihada, "Efficient Power Allocation for Video over Superposition Coding", *in Proc. IEEE International Conference on Advanced Information Networking and Applications (AINA)*, 2013.

[2] C. Lau, B. Shihada, and P.-H. Ho, "Empirical Evaluation of Superposition Coded Multicasting for Scalable Video", *in Proc. IEEE International Conference on Advanced Information Networking and Applications - The Ninth International Workshop on Heterogeneous Wireless Networks (HWISE)*, 2013.

[3] C. Lau, X. Zhang, and B. Shihada, "Video Quality Prediction over Wireless 4G", *in Proc. Pacific-Asia Conference on Knowledge Discovery and Data Mining*, Accepted, pp. 414-425, 2013.

Power Allocation: Why?

- Increase coverage and maintain high video quality for more users
- Incorrect power allocation between SPC layers can dramatically deteriorate video reception
- Corrupted enhancement layer data can affect the decoding process and degrade the video quality

Power Allocation: Simple Approach

- E : Total result energy
- E_1: Base layer energy
- E_2: Enhancement layer energy
- ***β*: Power allocation ratio**

$$E = E_1 + E_2$$

$$E_1 = \beta E$$

$$E_2 = (1 - \beta) E$$

- Larger β implies more energy is allocated to base layer

Evaluation

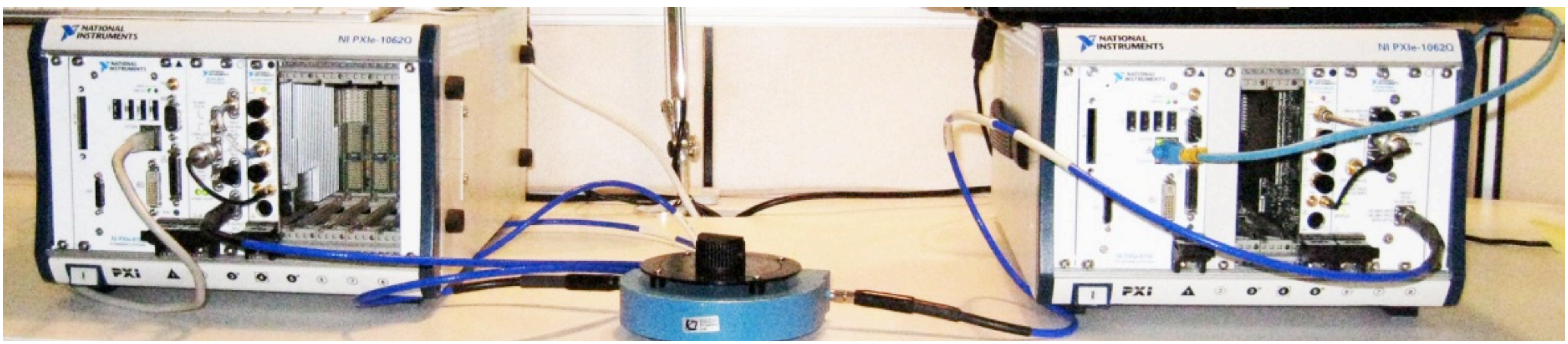
- Testbed components:
  - Wireless emulation
    - Emulated by two National Instrument PXIe boxes
    - Two boxes are connected through RF cables with an attenuator
    - Connected to PCs by Ethernet cable
  - Video
    - Base station (BS), Mobile-subscribing station (MS) emulated by two separate PCs
    - Transmitted video is stored for post analysis

Evaluation

- Three Scenarios
  - Generic Multicasting vs. SCM
  - SCM power allocation evaluation
  - Effects of Packet Error and Loss Rate (PELR) in Enhancement Layer
- Use Peak Signal-to-Noise Ratio (PSNR) as video quality assessment metric
- Collected 920 data samples

Testbed Layout

Transmitter	Receiver
CAASP-Tx	CAASP-Rx
National Instruments chassis PXIe-1062Q	
Embedded controller PXIe-8130	
IF transceiver PXIe-5641R	
RF Up converter PXI-5610	RF Down converter PXI-5600



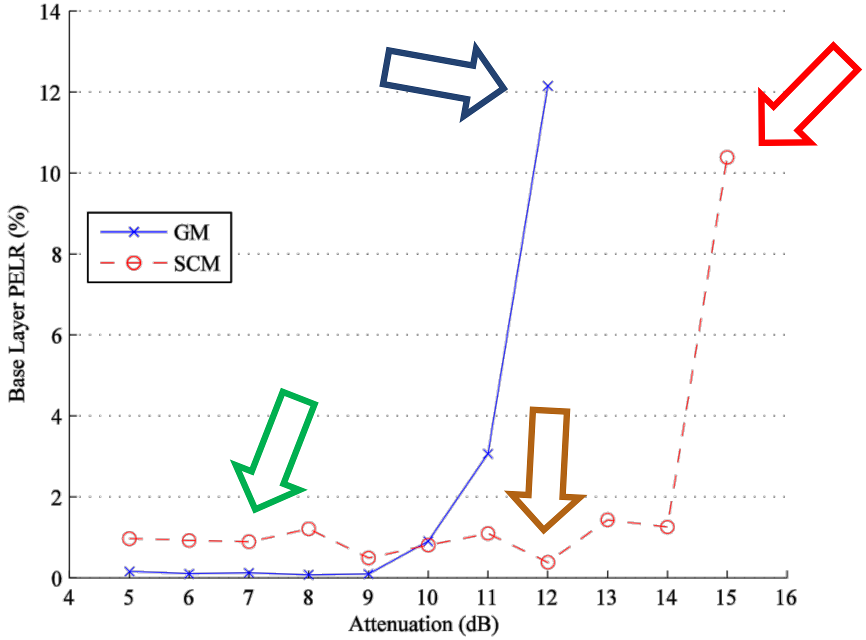
Wireless Network Characteristics

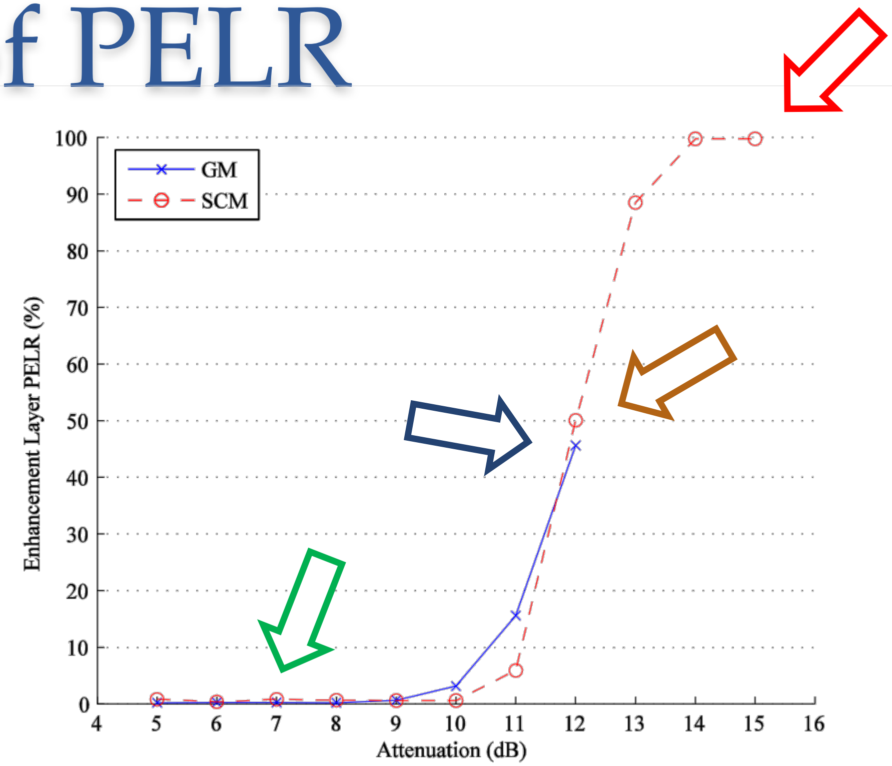
Transmission Type	SCM	GM
Air Interface	IEEE 802.16e-2005 DL Only	
Duplex Mode	TDD	
FFT Size	1024 Bytes	
Channel width	10 MHz	
Cyclic prefix	1/4	
Frame length	5ms	
B. Layer modulation	BPSK 1/2	16QAM 1/2
B. Layer capacity	821 kbps	3200 kbps
E. Layer modulation	QPSK 1/2	N/A
E. Layer capacity	1641 kbps	N/A
Radio Frequency	2.51 GHz	
Tx power	0 dBm	
Rx power sensitivity	0 dBm	

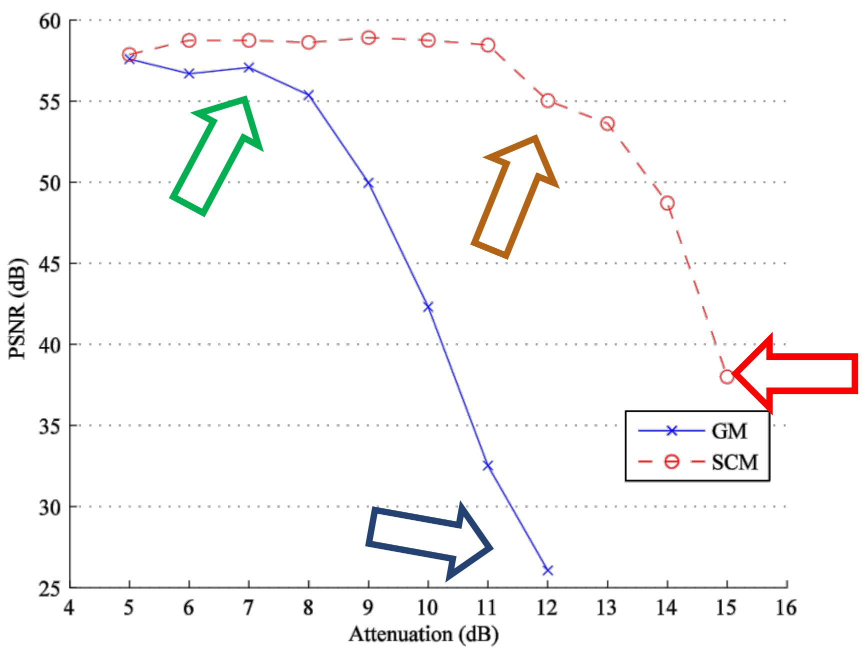
Video Characteristics

Properties	Value	
Number of Frames	1242 frames	
Frame Rate	30 fps	
Resolution	864 x 480 pixels	
Group of Picture	2	
Intra Period	4	
Symbol Mode	CAVLC	
Inter-layer Prediction	Yes	
Encoding Key Picture	Yes	
Layer	Base	Enhance
QP	35	25
Bitrate	521.63 kbps	1686.88 kbps
Encoding PSNR	56.01 dB	59.12 dB
Corr. SCM Modulation	BPSK 1/2	QPSK 1/2
Corr. GM Modulation	16QAM 1/2	

Effects of PELR

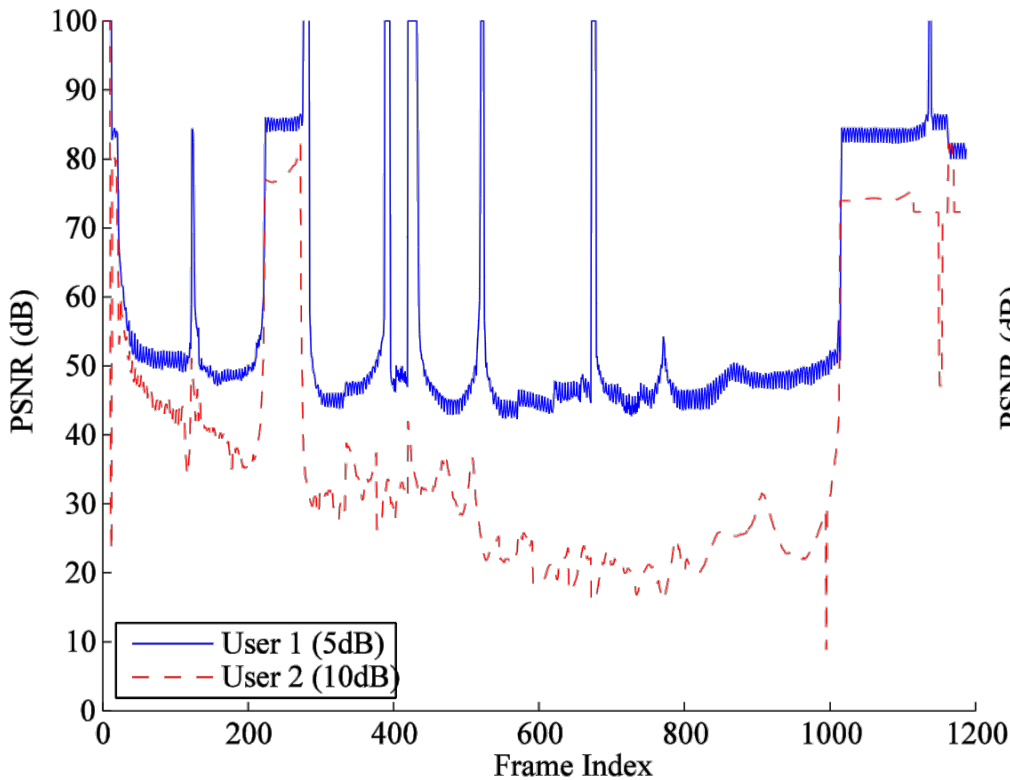




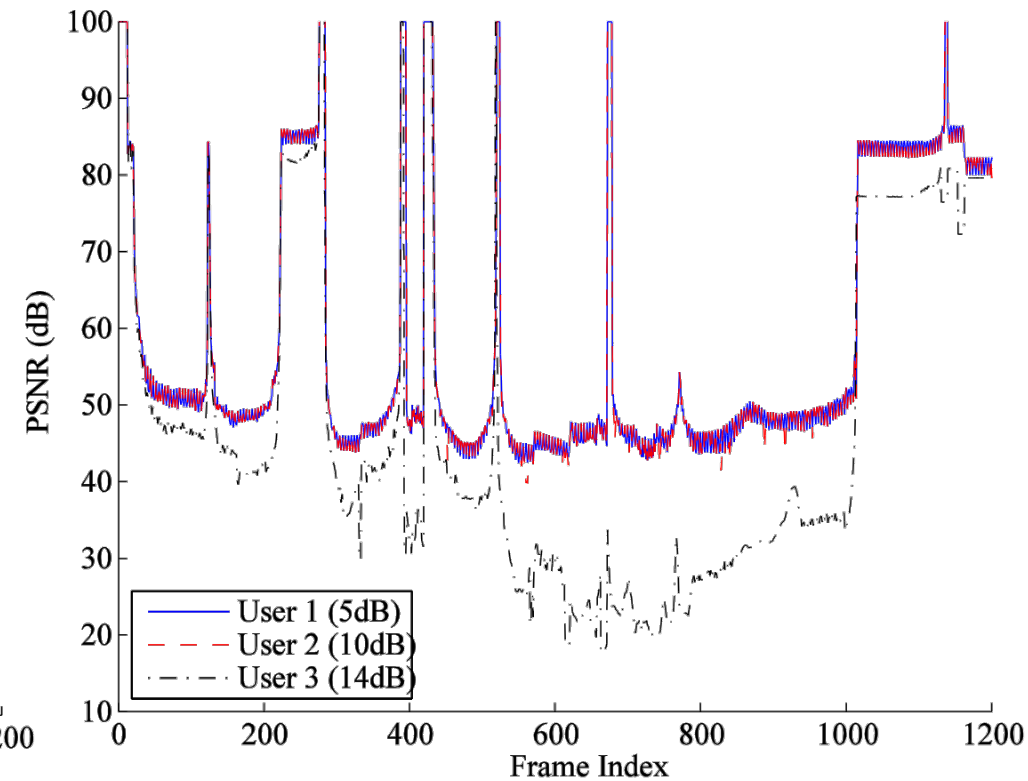


Atten<=7:	Good PSNR for both
7<Atten<= 12:	GM: PSNR Drop quick
7<Atten<= 11:	SCM: Remain good PSNR
Atten >= 12:	SCM: PSNR drops significantly
Atten = 15:	SCM: Unacceptable

Video PSNR Results



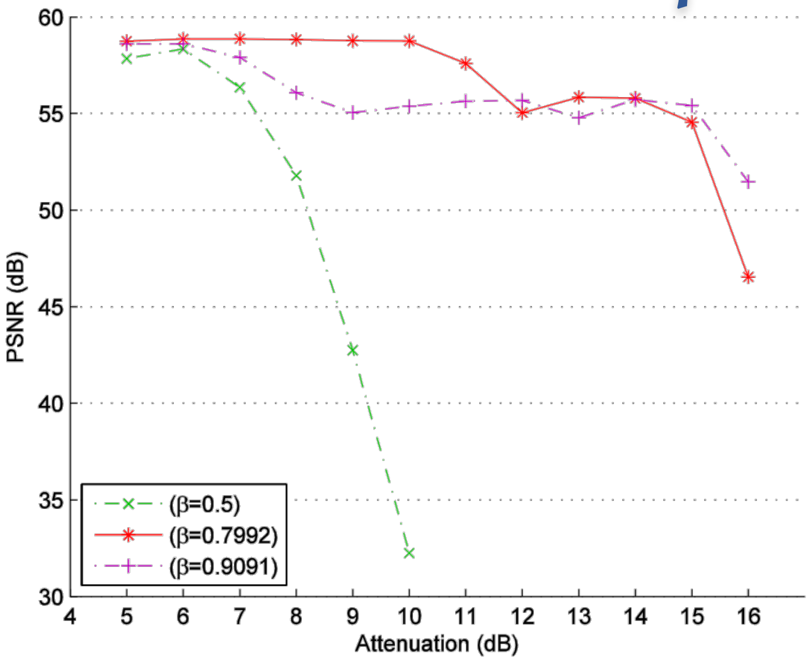
GM

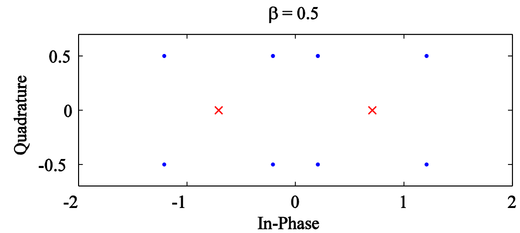


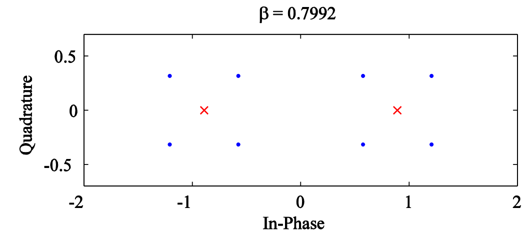
SCM

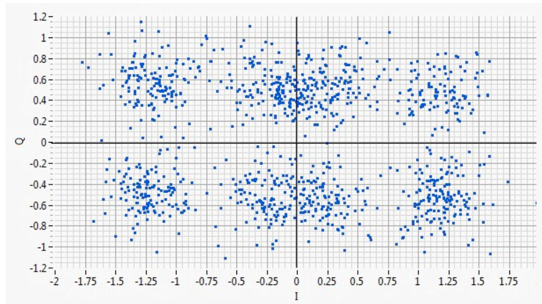
Received video PSNR of each frame in sequence

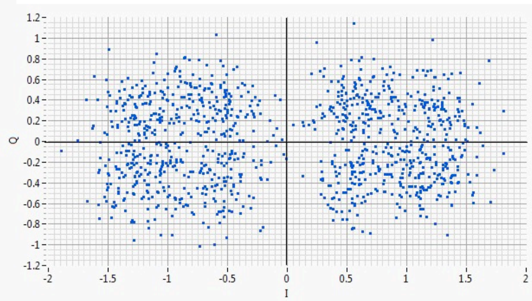
β Results

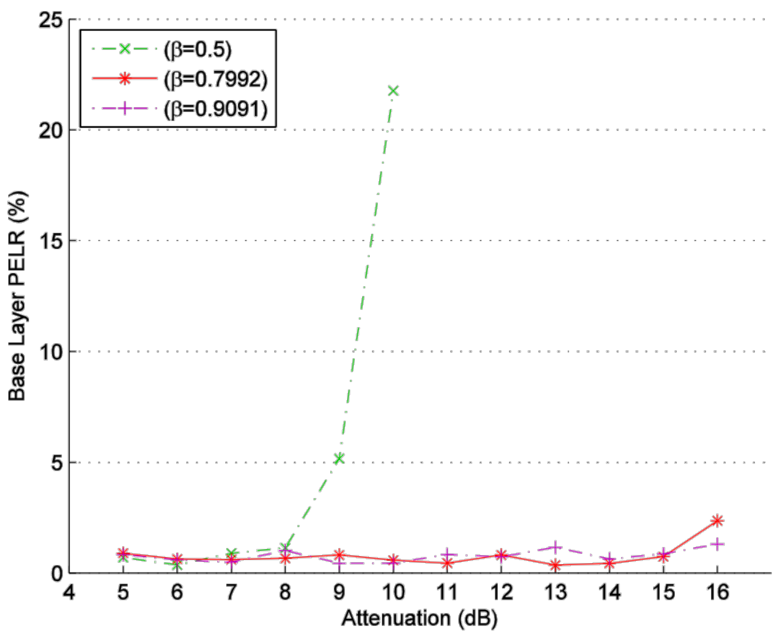


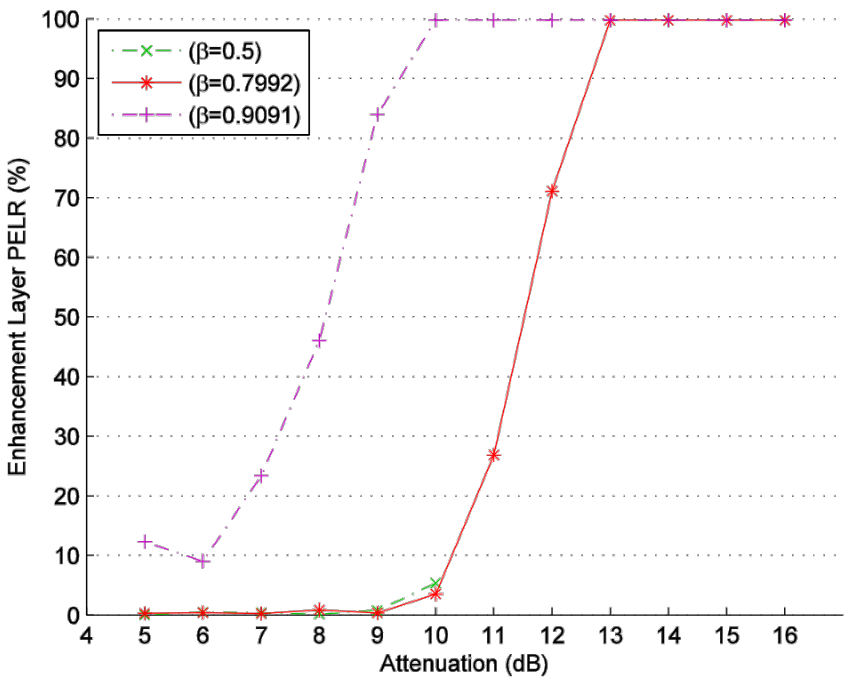






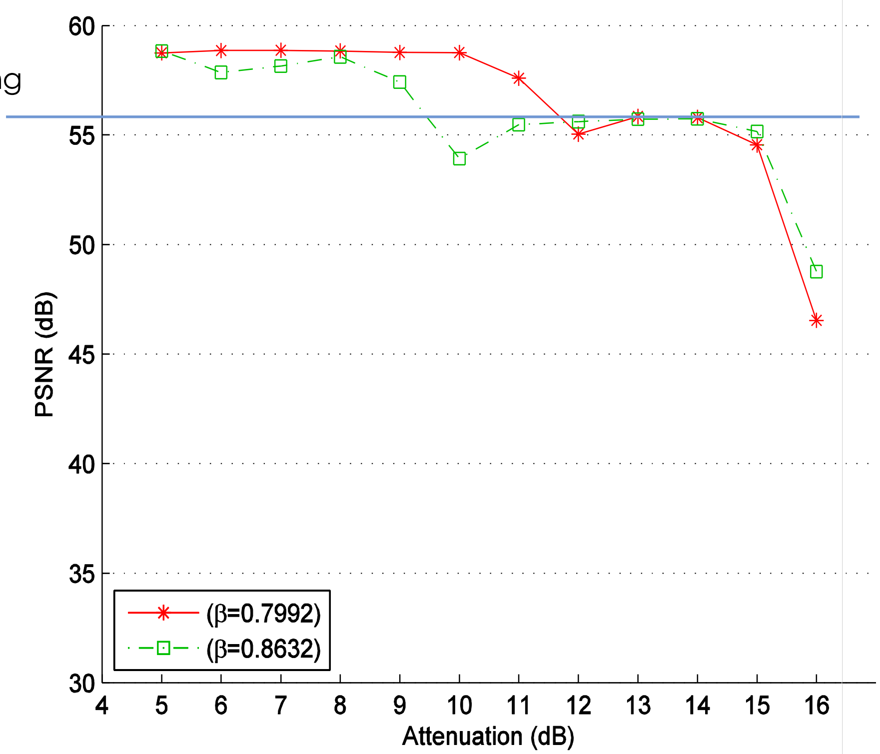


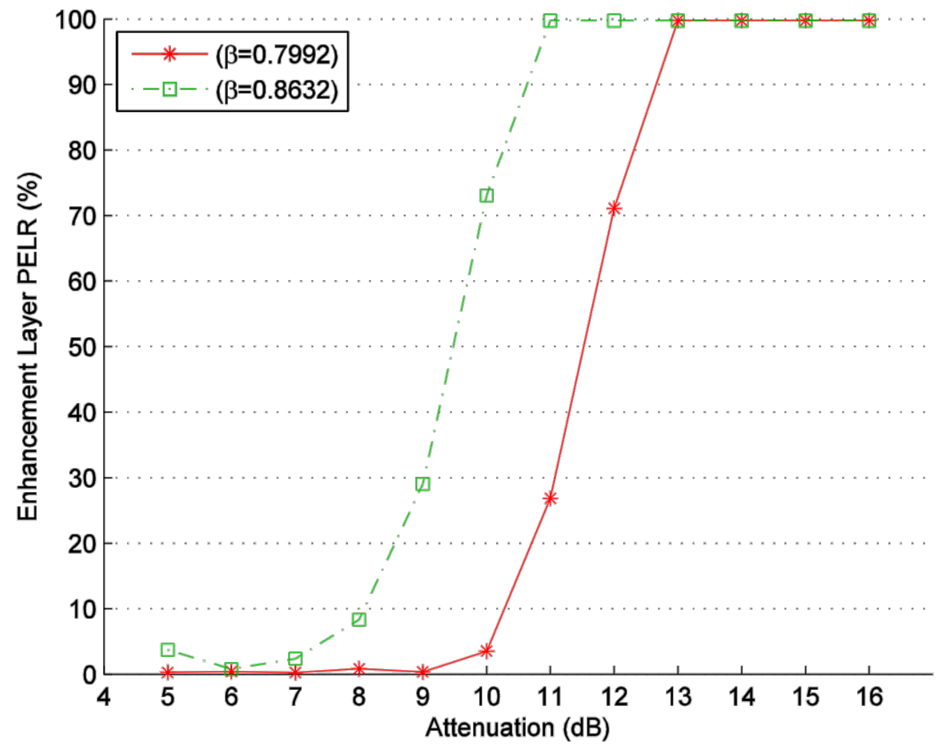




Effects of PELR in Enhancement Layer

Base
Layer
Encoding
PSNR
56.0dB





When En-PELR increases, it degrades the video quality in terms of PSNR. PSNR suddenly drops in the middle attenuation (7-12dB) and later increases to reach PSNR 55.8dB

Video Comparison

Conclusions

- SCM **effectively overcome the multiuser channel diversity problem**
- Appropriate power allocation ratio **(β = 0.7992)** which implies that the power for Base layer approximately **four times** higher than enhancement layer.
- Lost or corrupted enhancement layer packets can significantly affect the video quality.
- **Discarding corrupted or lost enhancement layer packets** is essential to maintain good video quality.

Thanks!

http://netlab.kaust.edu.sa