

# **Wireless Research Highlights at UC Davis**

## **WCA October 19 Meeting**

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Electrical and Computer Engineering

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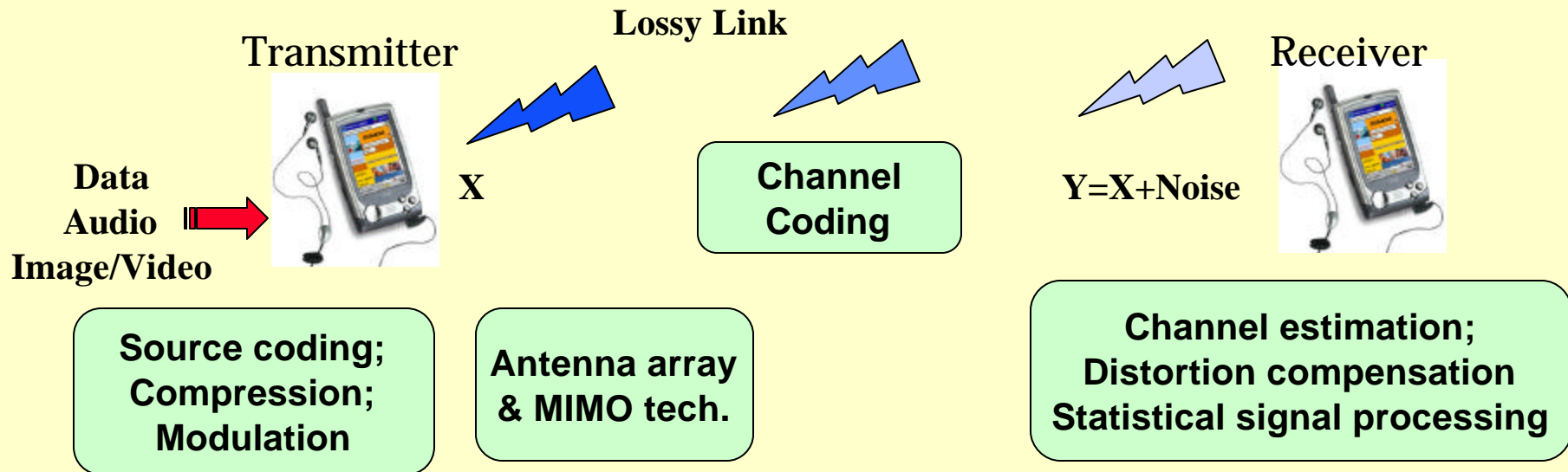
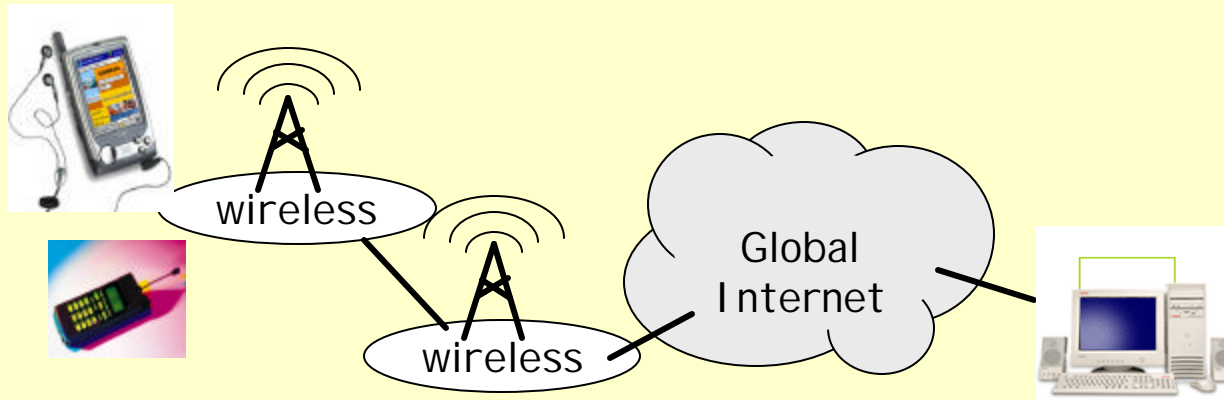
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# People @ UCD (in wireless)

- ECE Department of 34 professors in circuits, optics, solid state, communications, and computer engineering;
- 900 UG students and 200 graduate students
  
- 8 faculty members in wireless related research area
- PHY and integration with above
  - Bernard C. Levy (communications and array processing)
  - Zhi Ding (channel estimation, MIMO and ARQ)
  - Shu Lin (world renowned coding expert)
  - Khaled Abdel-Ghaffar (coding)
  - Jamal Tuqan (multi-rate signal processing and comm.)
- Networking and Applications
  - Chen-Nee Chuah (networking)
  - Qing Zhao (power constrained wireless networks)
  - Mihaela van der Schaar (video processing /applications)

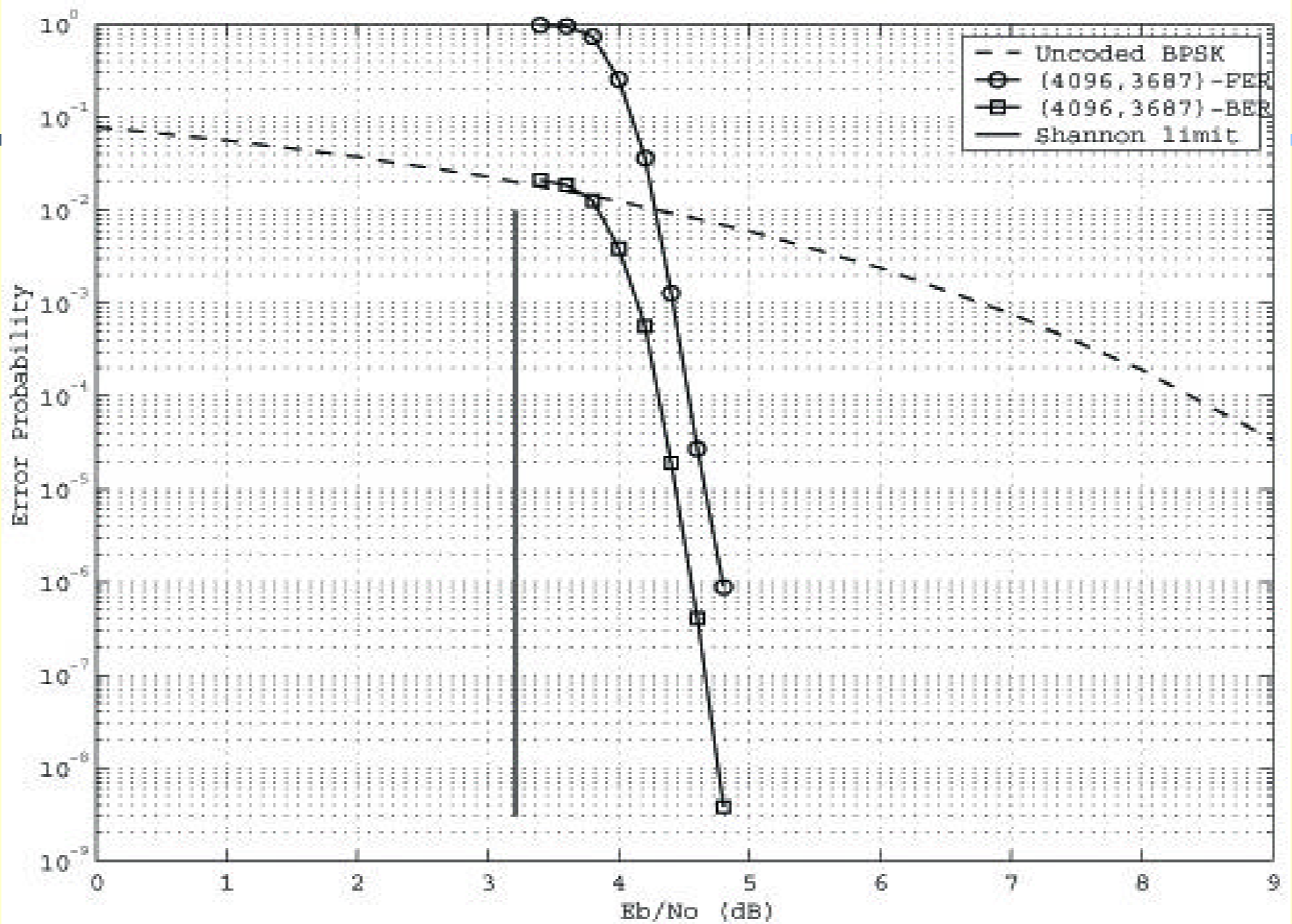
# What do we do?



# Geometric and Algebraic Construction of LDPC Codes

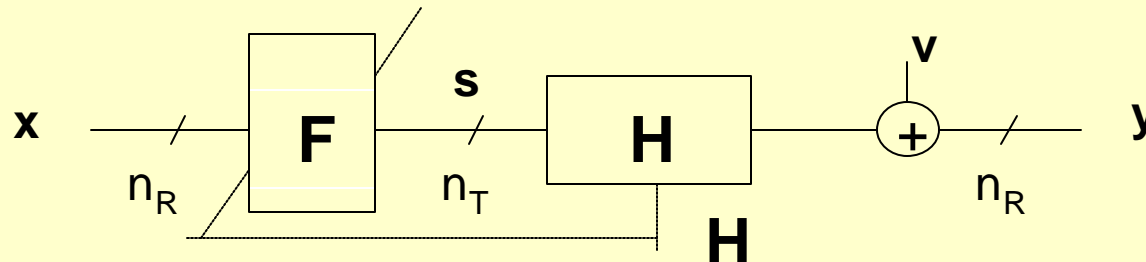
*Professors Shu Lin and Khaled Abdel-Ghaffar*

- Low Density Parity Check (LDPC) codes
  - were discovered in the early 60's
  - recently rediscovered and shown to form a class of Shannon limit approaching codes.
  - most known constructions are random in nature
- Constructions of LDPC codes based on finite-geometries and the algebraic theory of finite fields
  - perform very close to Shannon limits;
  - compare favorably with randomly constructed codes;
  - have regular (quasi-cyclic) structures;
  - Can be implemented at low cost, low complexity.
- Developing MIMO specific LDPC codes via density evolution.
- Iterative decoding of Reed-Solomon codes
- Newly developed LDPC codes are proposed as standard for NASA and 10Gb/s Ethernet



# Robust MIMO Precoder Design with Imperfect Channel Knowledge (Professor Levy & Y. Guo)

- A precoder MIMO system with imperfect CSI at the transmitter



- When the estimate channel  $\hat{\mathbf{H}}$  is different from the actual channel  $\mathbf{H}$ , robust precoder design can be formulated as a min-max problem

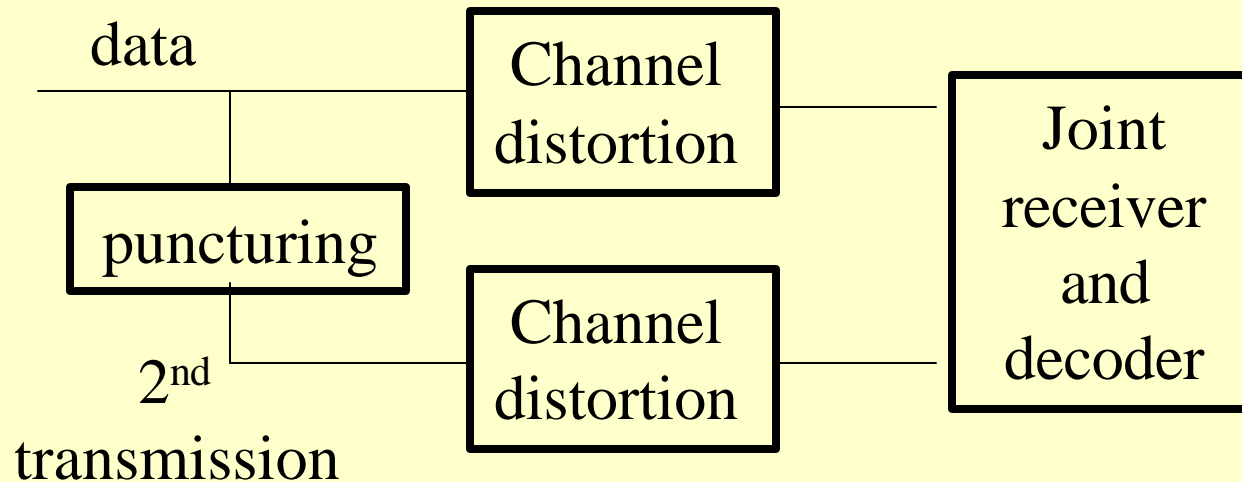
$$\min_{\mathbf{F}} \max_{\mathbf{H}_? \in \mathbf{B}} J(\mathbf{F}, \mathbf{H}_?) = \left\| [\hat{\mathbf{H}} + \mathbf{H}_?] \mathbf{F} - \mathbf{I}_{n_R} \right\|_{\mathbf{F}}^2$$

$$\mathbf{B} = \{ \mathbf{H}_? : \left\| \mathbf{H}_? \right\|_{\mathbf{F}}^2 \leq c \}.$$

- The min-max problem can be solved by convex optimization techniques since the objective function  $J(\mathbf{F}, \mathbf{H}_?)$  and the ball  $\mathbf{B}$  are convex in  $\mathbf{F}$  and  $\mathbf{H}_?$ .

# Channel estimation and equation in punctured ARQ (PARQ) (with J. L. Roberson)

- Punctured ARQ to improve throughput



- 2<sup>nd</sup> transmission requires no pilot training
- Joint detection and decoding amenable to turbo processing

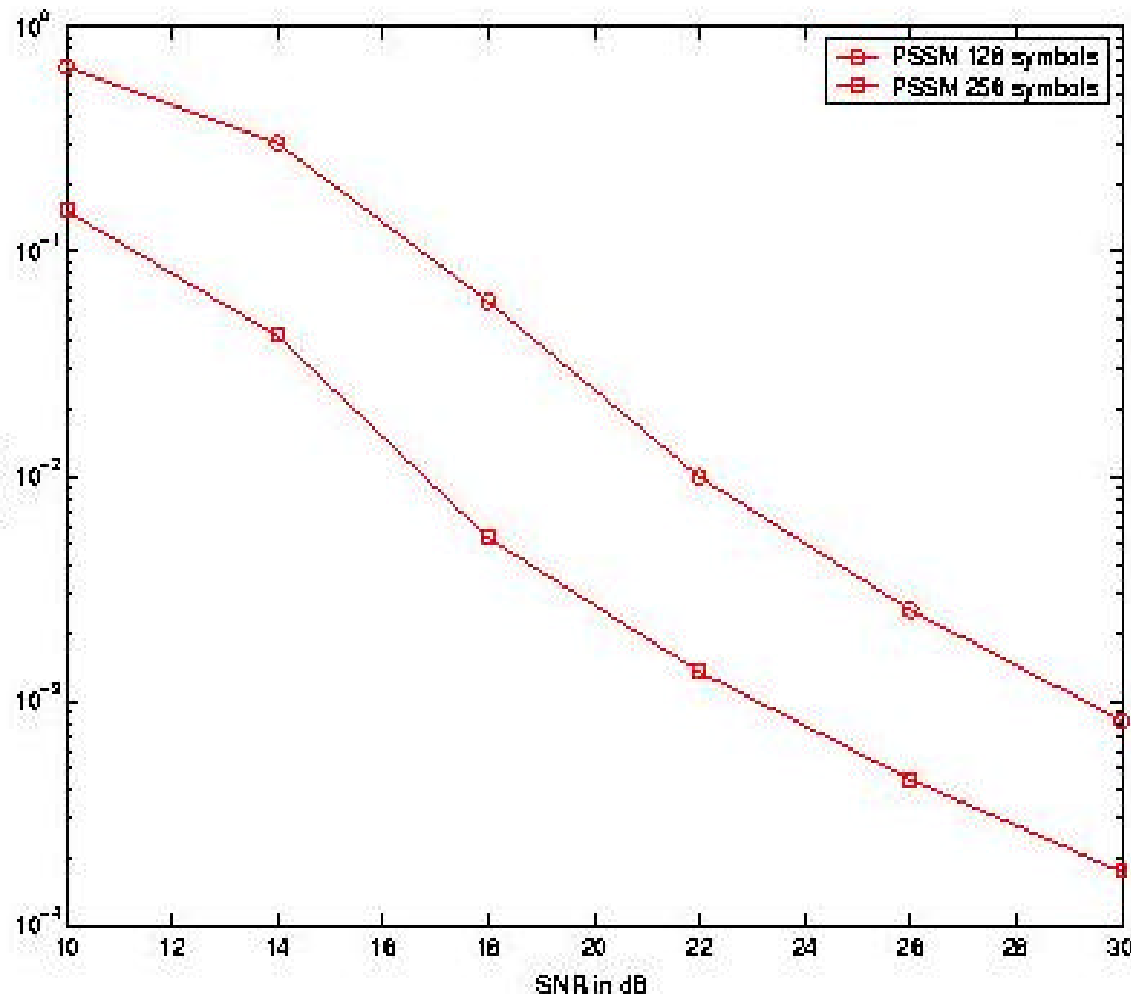
# Bandwidth conservation via puncturing

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- Puncturing shortens retransmission time.
- Even correctly detected symbols may be resent, their interaction through precoding and channels can provide information on erroneous symbols.
- Puncturing is simple to implement.
- Channel estimation can be improved.



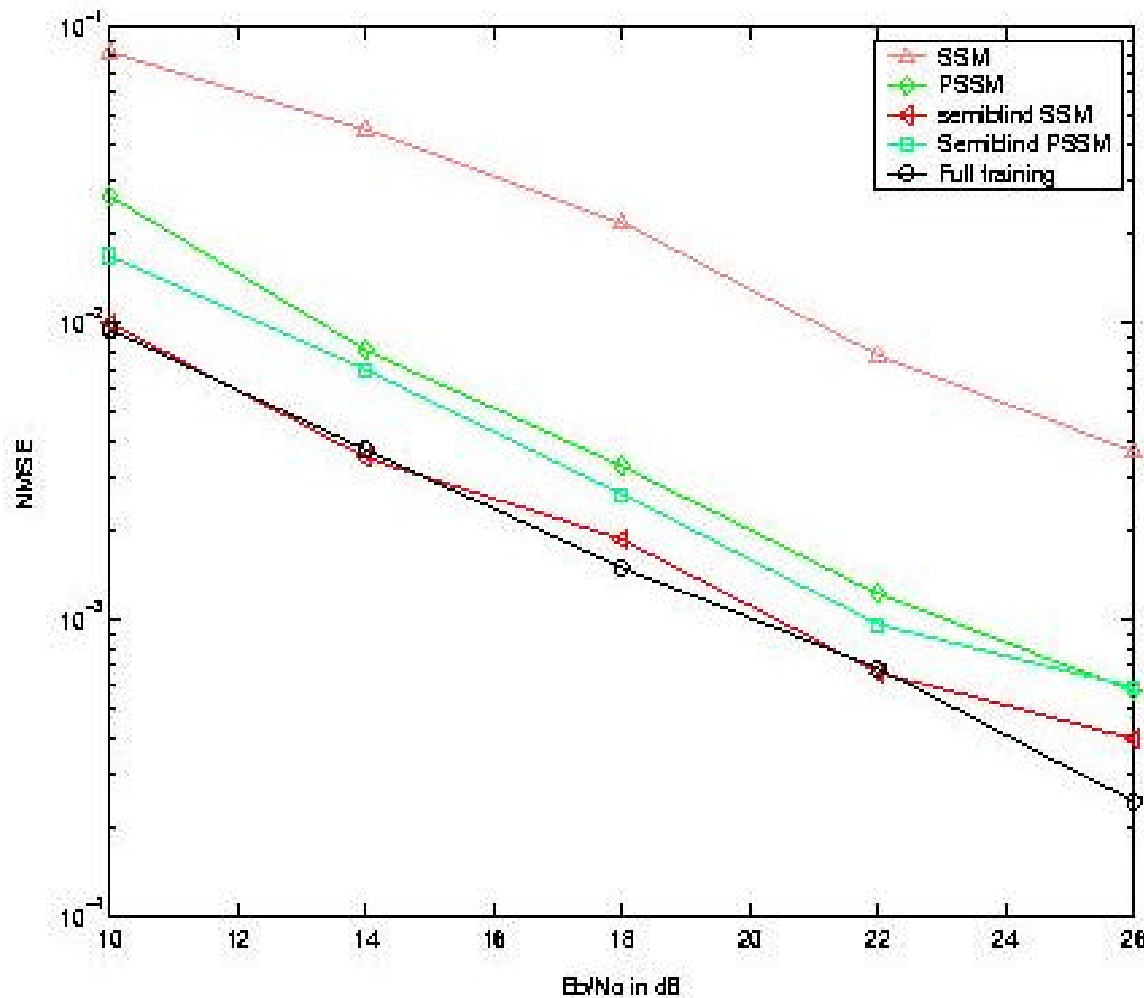
# Blind Simulations



**Normalized Mean Squared Estimation Error versus SNR over 20 random channels**

- $N_{symbols} = 128, 256$
- $N_{channels} = 20$
- Algorithm: PSSM (red)
- Same Channel

# Semiblind Simulations



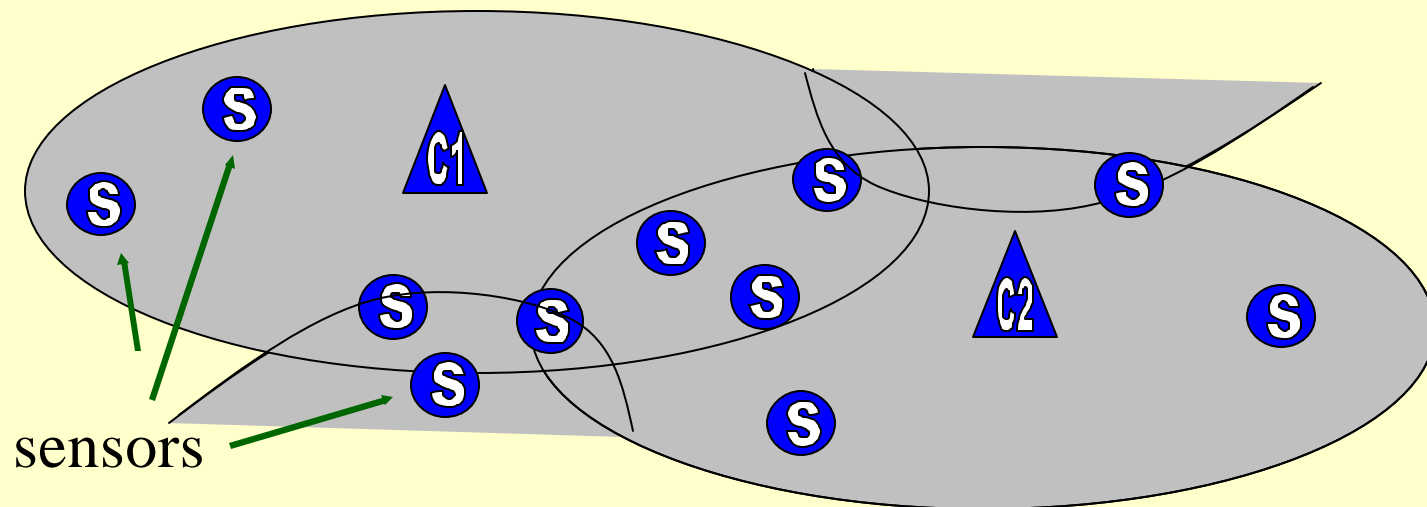
Channel estimation performance for the retransmission segment only

- number of message symbols = 128
- number of training symbols = 16
- $N_{channels} = 20$

# Coding in Video Networks

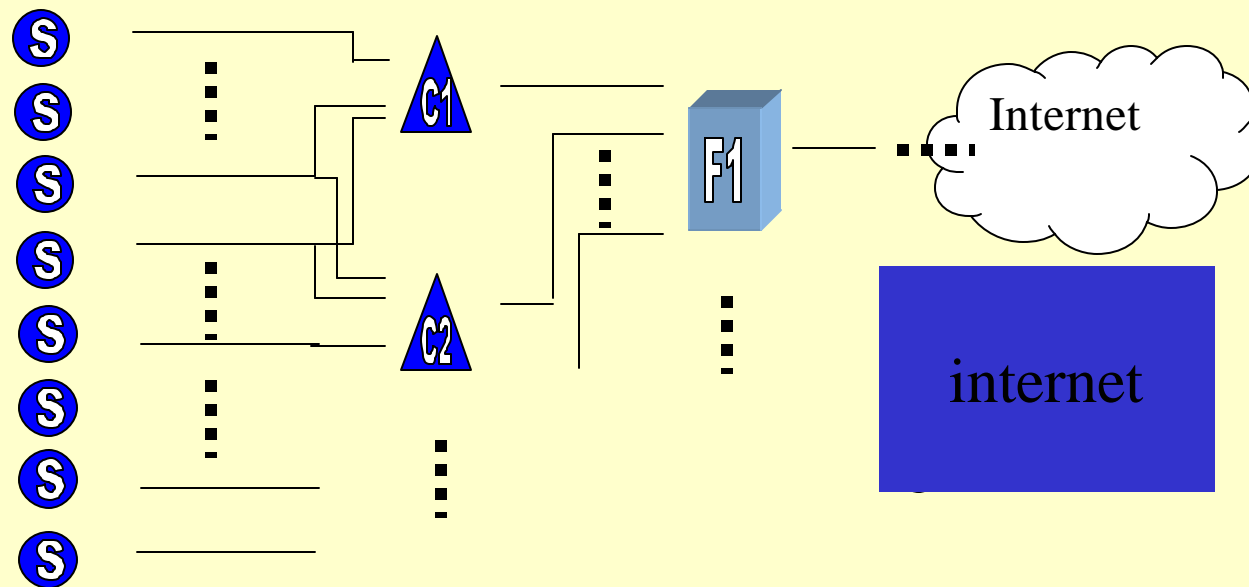
(M. Vanderscharr, Z. Ding, and H. Sun)

- Distributed user networks and data centers



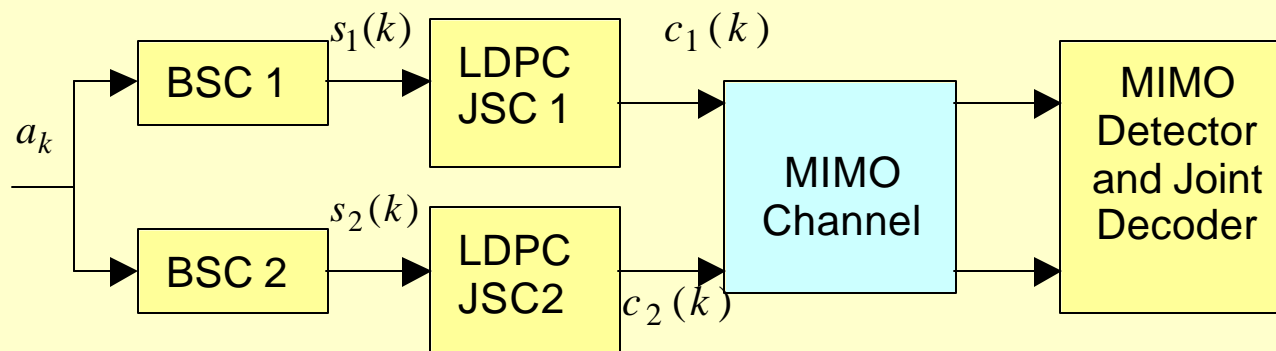
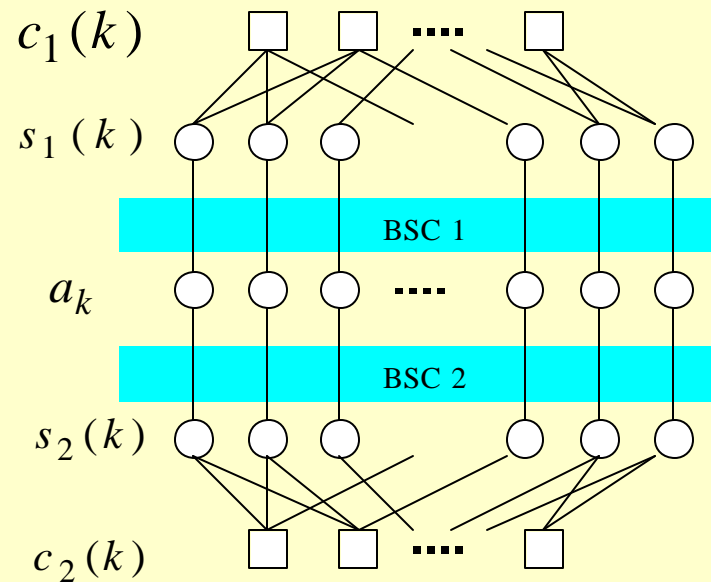
- Each user is serviced by multiple centers
- Each center connects to higher nodes using wireless media in a hierarchical network

# Path diversity in hierarchical networks



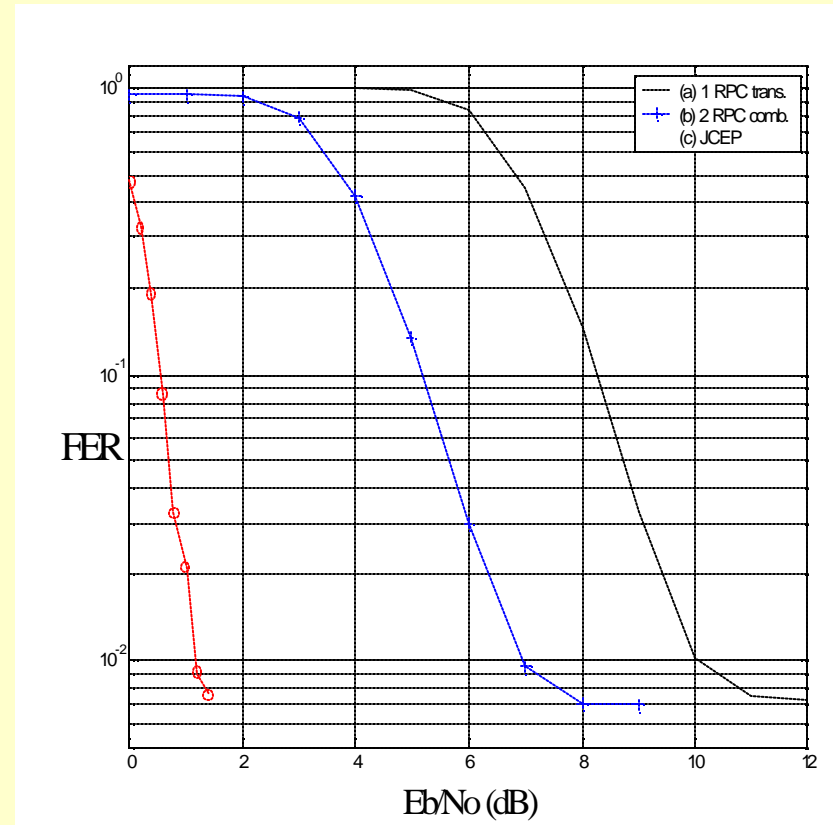
- Path diversity can be exploited in data compression and error protection

- Joint compression and error protection (JCEP) codes and turbo detector



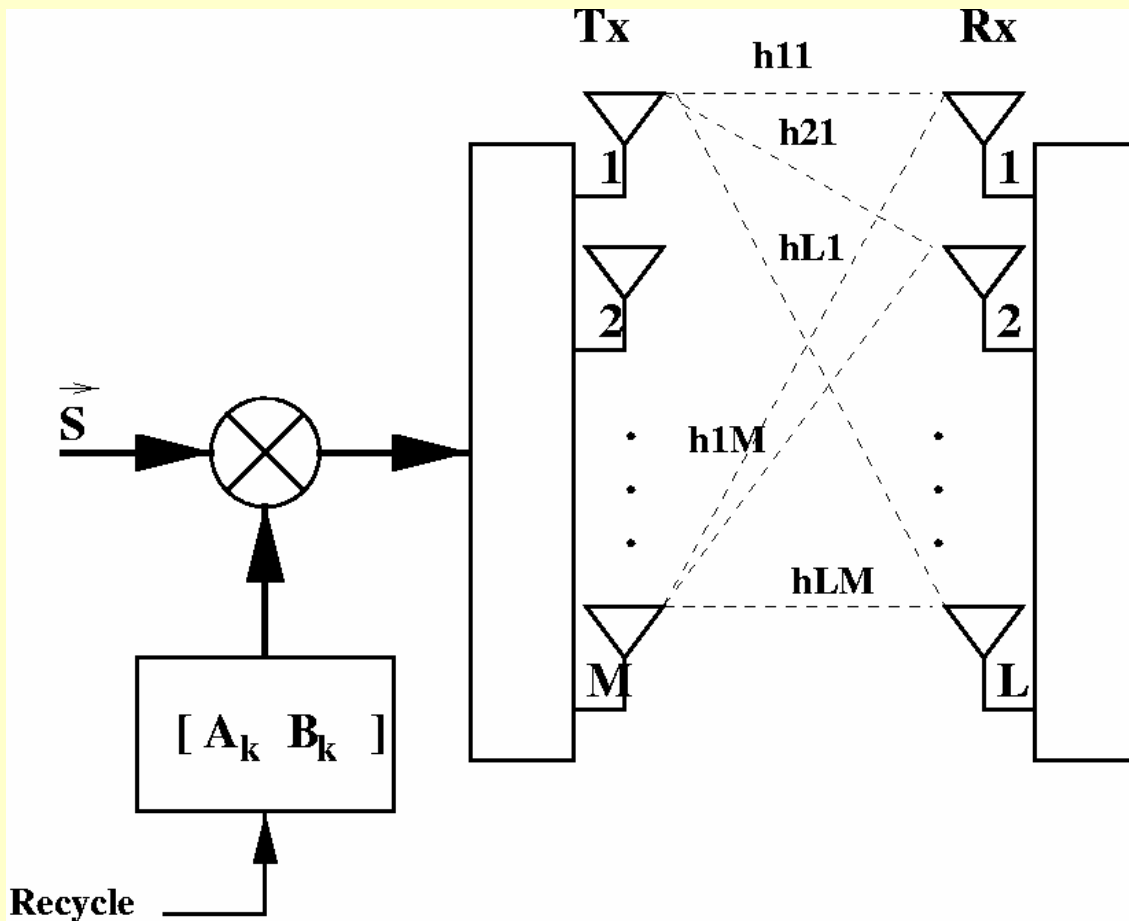
## Simulation Example

- LDPC (1020,766) code [Lin] was used for JCEP
- compression ratio=5/6, each path transmits all parity bits (254) and half message bits (383) for 766 source message bits
- BSC BER=1.e-5
- 20 iterations in soft decoding



## Channel estimation in space-time coded systems (with N. Ammar)

- Space-time codes (STC) provides a powerful tool.
- Channel knowledge required at receiver for decoding.



# Blind channel estimation results

- Noisy wireless link: STBC with 3 Tx antennas over 4 epochs.
- STBC:

$$\begin{bmatrix} s_1 & -s_2^* & \frac{s_3^*}{\sqrt{2}} & \frac{s_3^*}{\sqrt{2}} \\ s_2 & s_1^* & \frac{s_3^*}{\sqrt{2}} & -\frac{s_3^*}{\sqrt{2}} \\ \frac{s_3}{\sqrt{2}} & \frac{s_3}{\sqrt{2}} & \frac{-s_1 - s_1^* + s_2 - s_2^*}{2} & \frac{s_1 - s_1^* + s_2 + s_2^*}{2} \end{bmatrix}$$

- Performance Criteria:  $NMSE \triangleq \frac{\|\mathbf{H} - \alpha \hat{\mathbf{H}}\|_F^2}{\|\mathbf{H}\|_F^2}$  channel  $\hat{\mathbf{H}}$  estimate.
- $\alpha$  is resolved by linear projection

$$\alpha = \frac{\text{trace}(\hat{\mathbf{H}}^H \mathbf{H})}{\text{trace}(\hat{\mathbf{H}}^H \hat{\mathbf{H}})}$$

- Results obtained for 16-QAM signals.



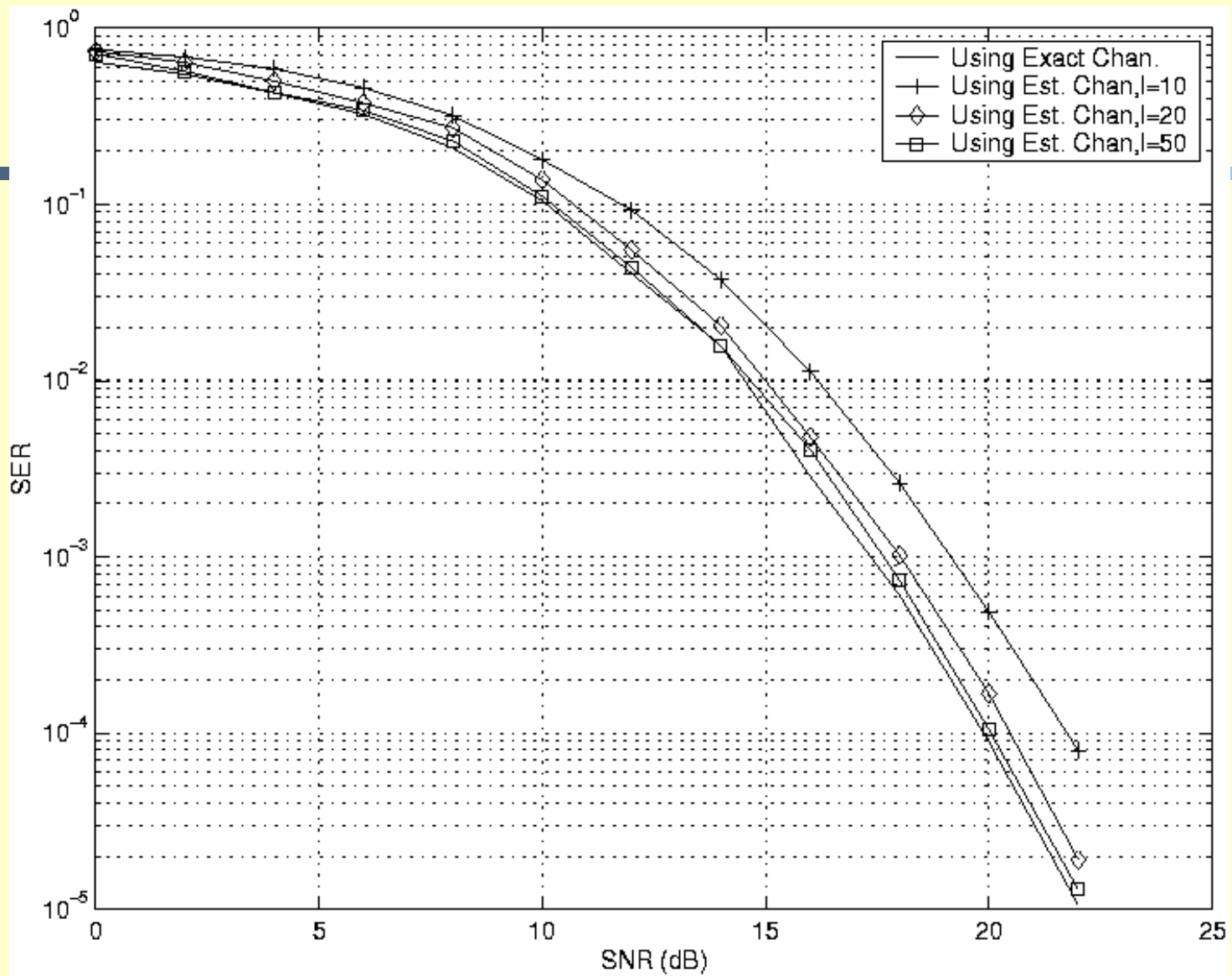
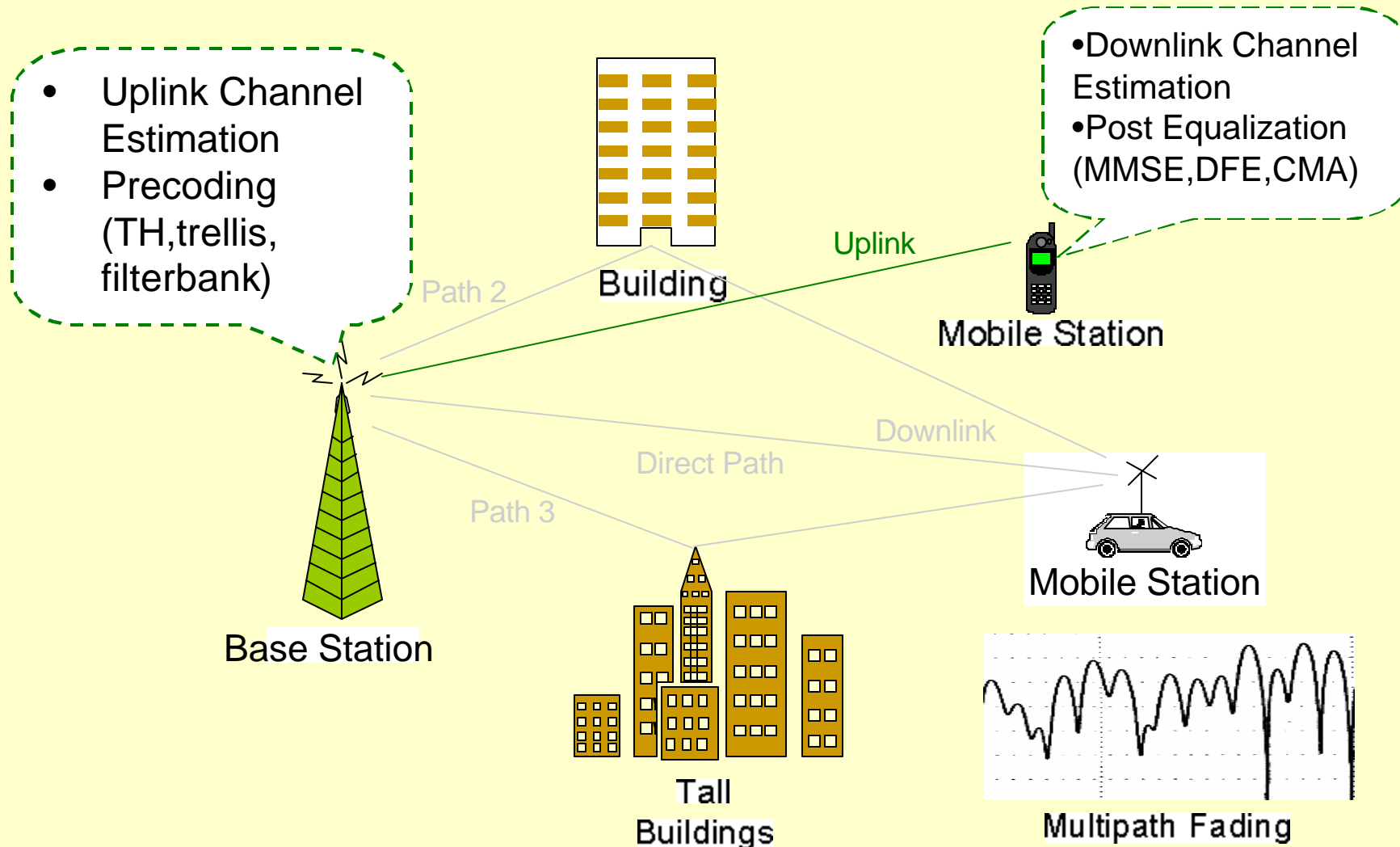


Figure 3: SER versus SNR, ML decoder  $l$  uses exact and estimated channels,  $\mathbf{H} : 2 \times 3$

# Forward channel estimation for pre-coding in wireless communications (with X. Fei Dong)

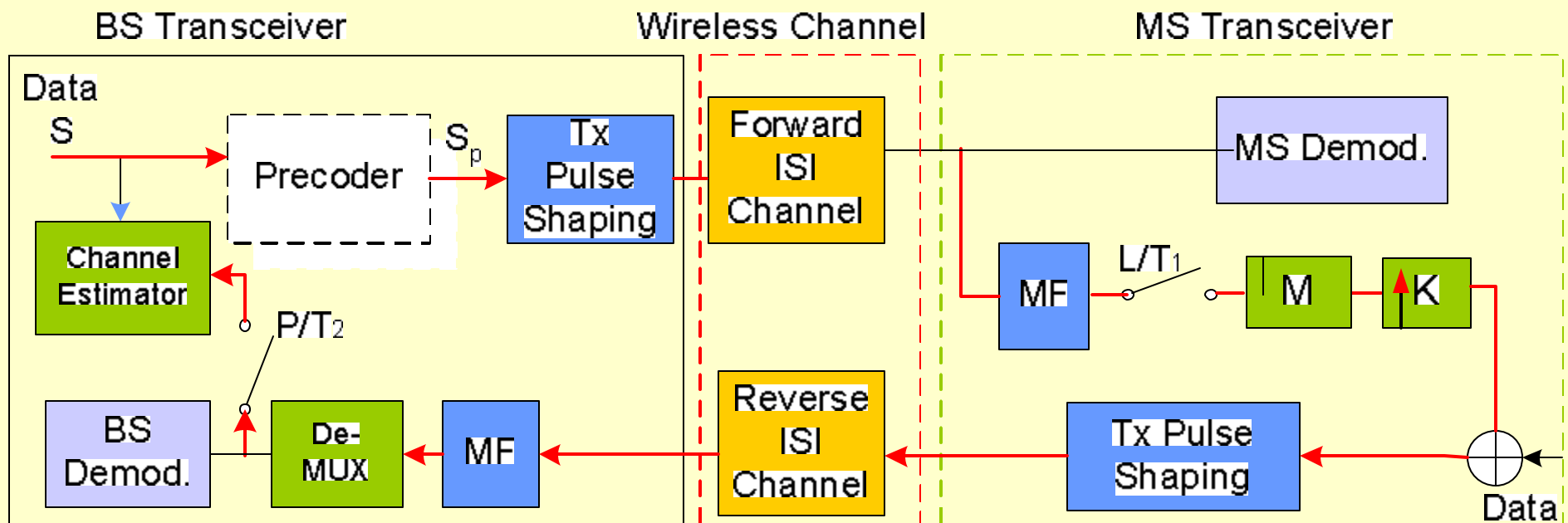


# Drawbacks of Traditional Systems

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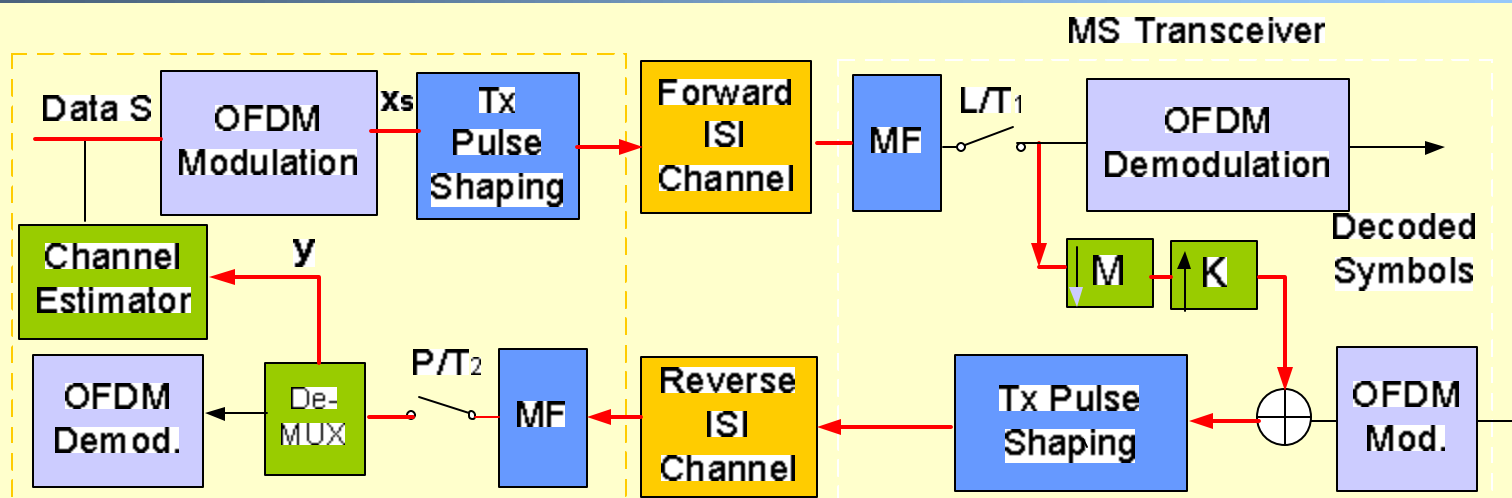
- Downlink channel estimation and compensation are implemented in MS.
- Training consumes downlink channel bandwidth.
- Precoding requires MS (mobile-station) to return channel estimates.
- BS (base-station) is rich in resources, but MS runs on battery and must save power.

# Bent-pipe (Precoded) Feedback System



A (precoded) wireless communications system with decimated feedback [Xu, ICC2001] for forward channel estimation.

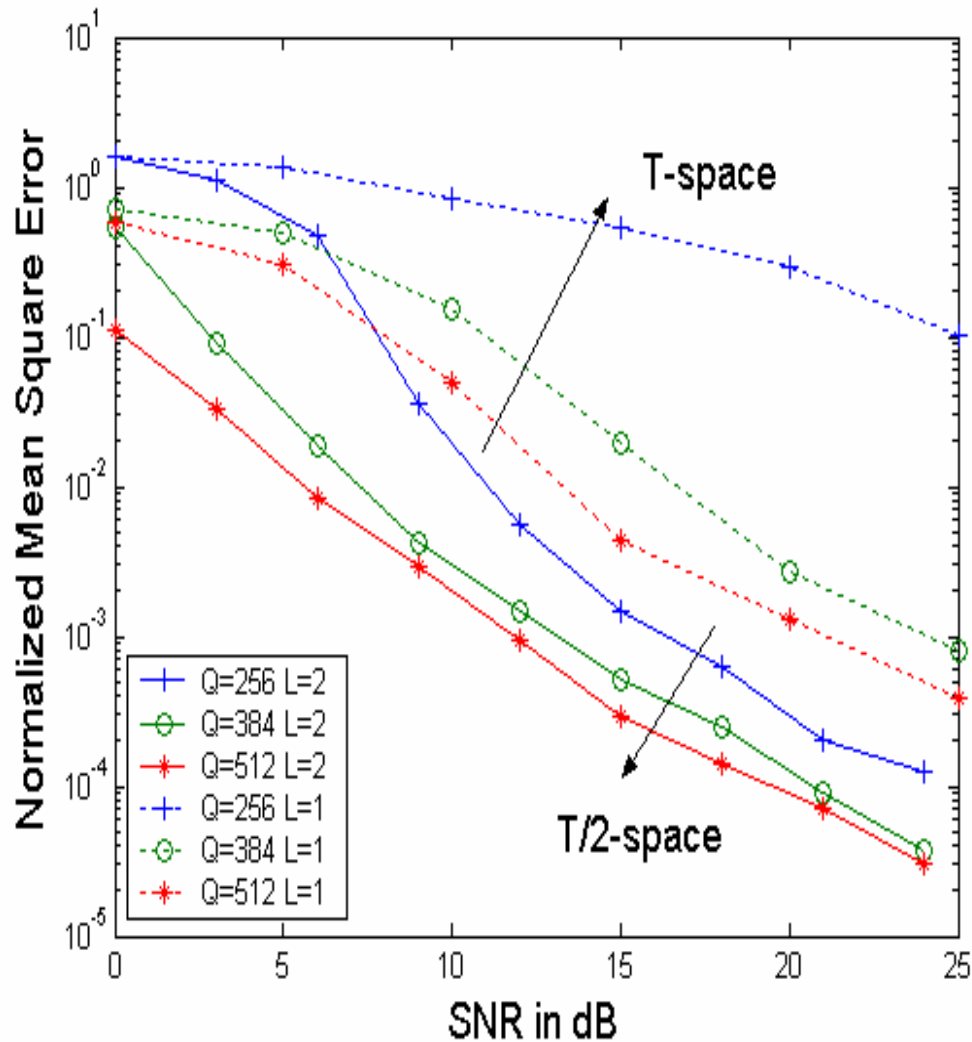
# OFDM with Feedback



## OFDM with decimated feedback.

- OFDM modulated symbols for estimation
- Sampled, unprocessed data directly back to BS

## NMSE of OFDM Channel Estimation

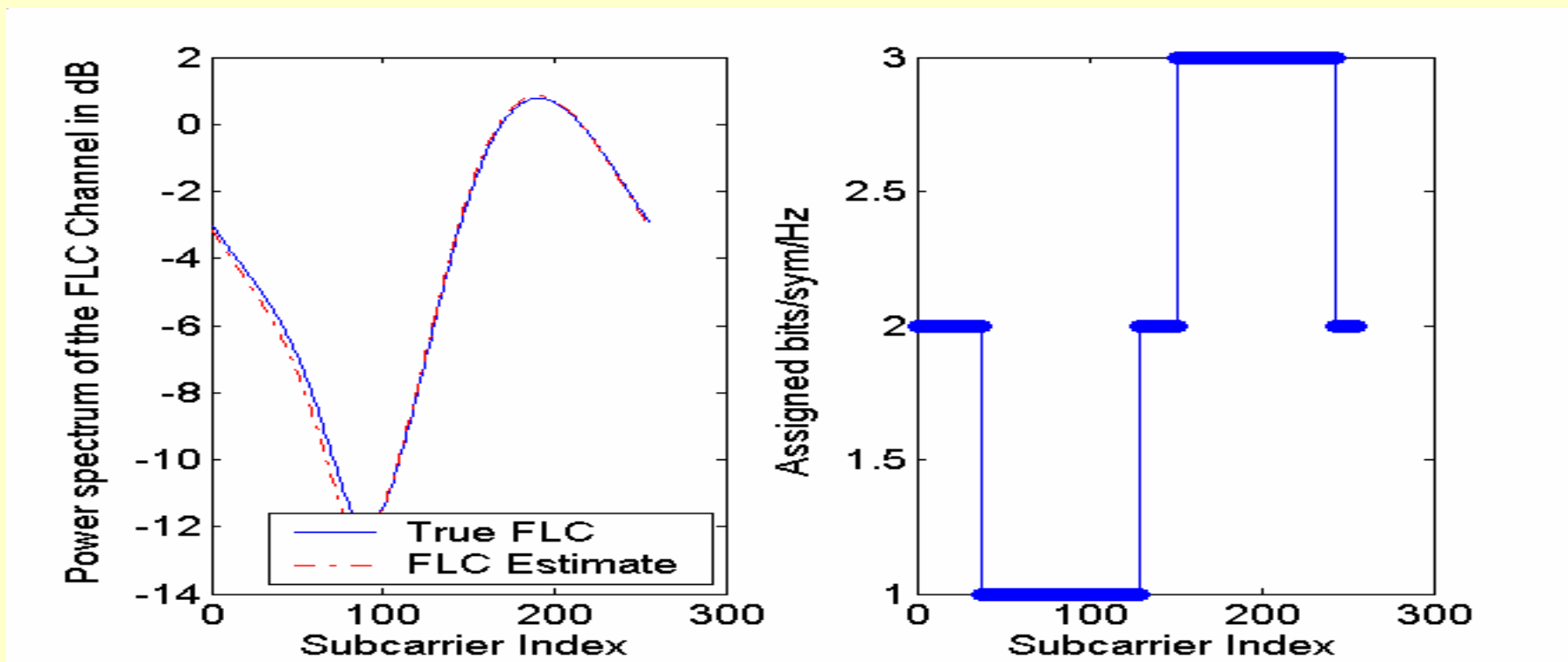


### Simulation Parameters

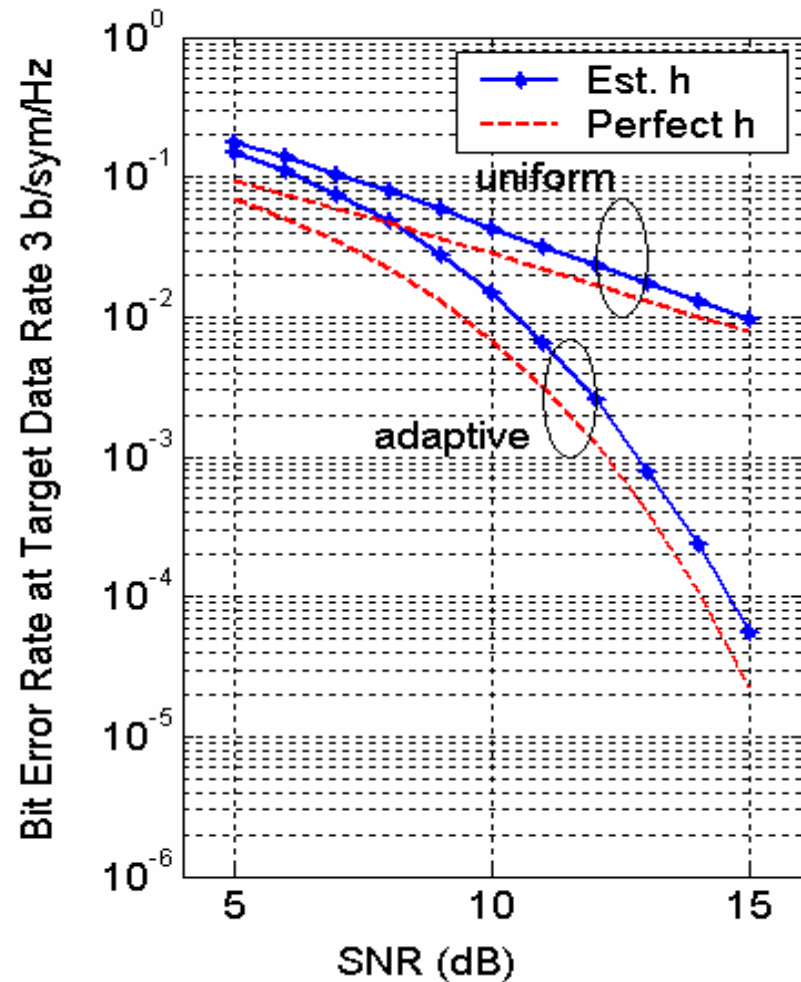
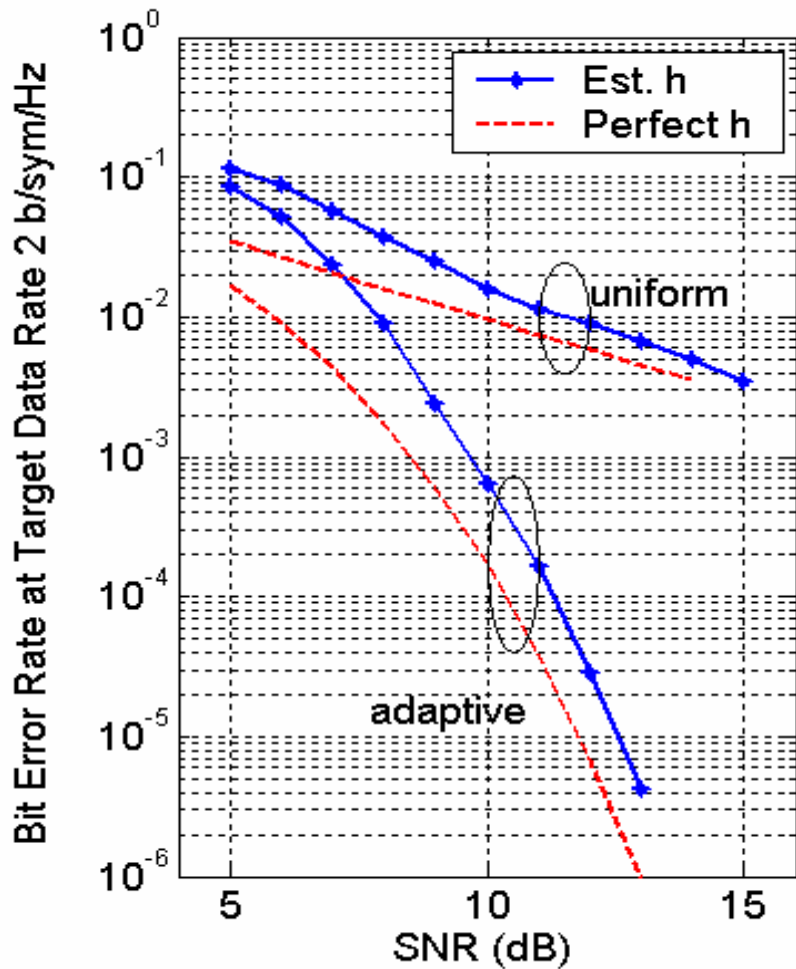
- Q: feedback data size
- Down sampling factor  $M=5$
- Oversampling ratio
  - *in MS*  $L=2$
  - *in BS*  $N=1$
- 100 independent channels

# Adaptive Modulation

- High SNR subchannels get more bits/symbol.
- Water-pouring power distribution is optimal.
- Bit loading algorithm by Chow & Cioffi [TCOM, 95]



# BER



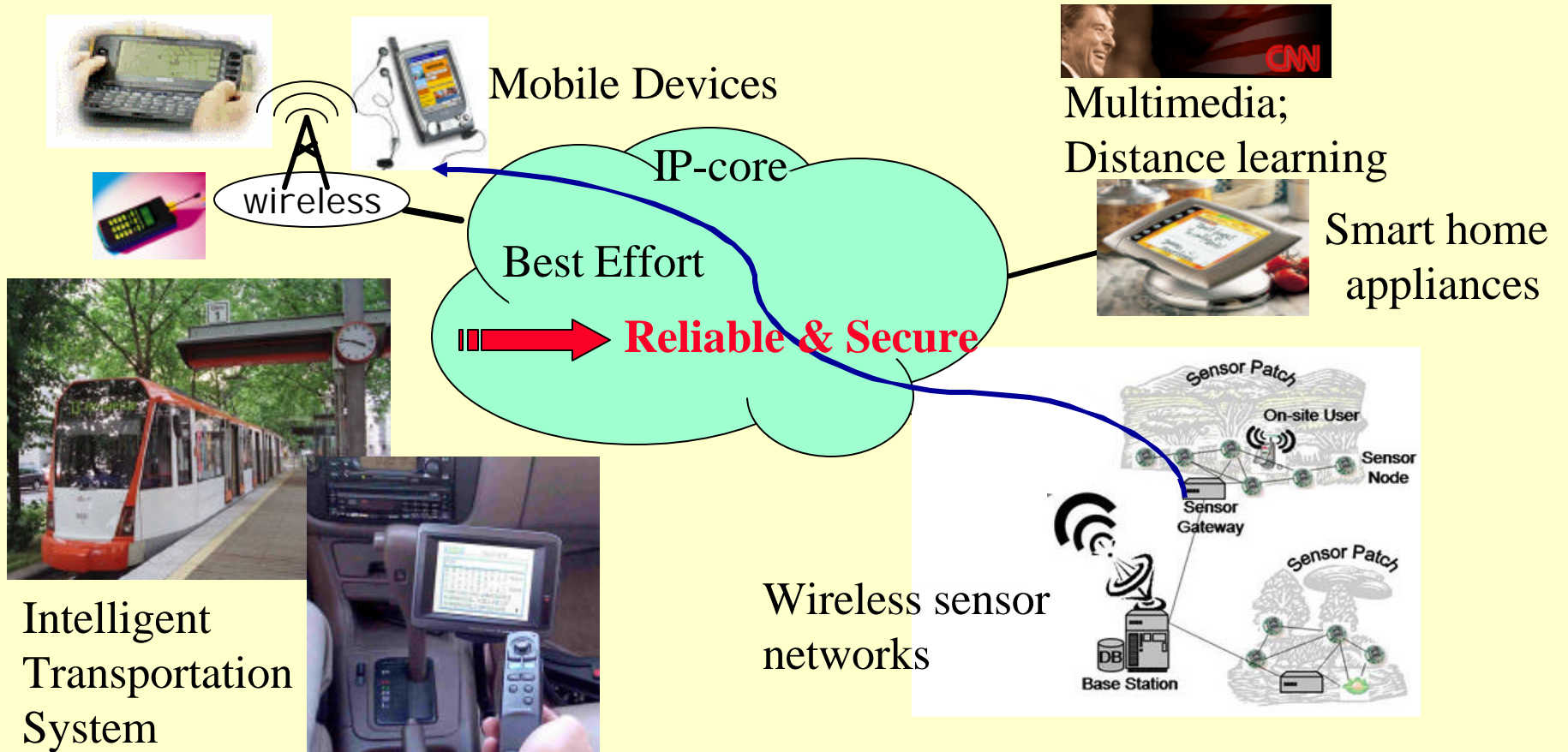
BER of bit loaded and uniform OFDM



# RUBINET Robust & ubiquitous Networking Research Group

*Faculty: Chen-Nee Chuah*

Ubiquitous networking, computing & storage connected via wide-area Internet: **Fault-resilient, stable, and secure routing**



# Next-generation network infrastructure: Requirements & Challenges

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## Desired properties

- Resilient against failures
- Stable
- Secure, verifiable routes
- Scalable
- Support Mobility
- Flexible services

## Challenges

- Heterogeneous application requirements
- Diverse device capabilities & access technologies
- Dynamic network/traffic conditions
- Distributed network control

# RUBINET Research Projects

1. **RoSE: Robust, Secure, & Efficient Routing**
  - Measure and model routing failure characteristics in wide-area Internet routing
  - Design statistical algorithm for detecting anomalies
  - Design an overlay policy control architecture
2. **EMITS/DETER: Ensuring Security of Routing Plane**
  - Vulnerability analysis and develop defense mechanisms
3. **Joint optimization at source/channel/transport layers for multimedia streaming**
4. **DRIVE: Dissemination and Retrieval of Information via Vehicular Wireless Network**
  - Societal-scale applications, e.g., intelligent transportation system, amber alert, disaster relief

Research webpage: <http://www.ece.ucdavis.edu/rubinet>

# Industrial Collaboration

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- Wireless research at UC Davis consists of a wide range of projects aimed at the future of wireless systems.
- Collaboration with: Intel, Nortel, Sprint, ETRI, LSI Logic, Phillips, NASA, Centillum, LLNL, Sandia, etc.
- We welcome new industrial partners.
- Contact <http://www.ece.ucdavis.edu/~zding>

# Our Wireless Activities in a Big Picture

