MMT Workshop

m17330

Cross Layer Optimization (CLO) for reliable video delivery over mobile wireless networks

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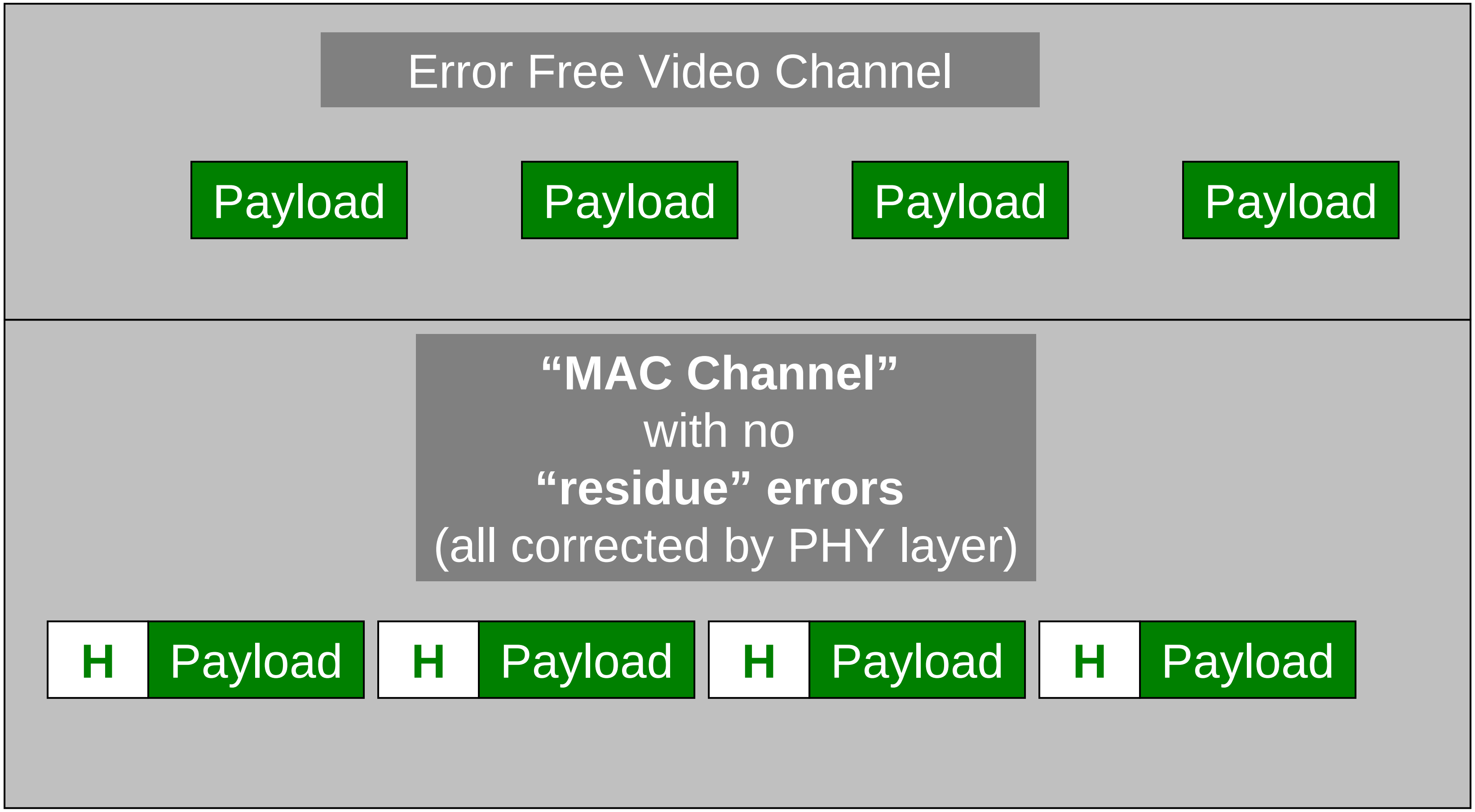
Problem

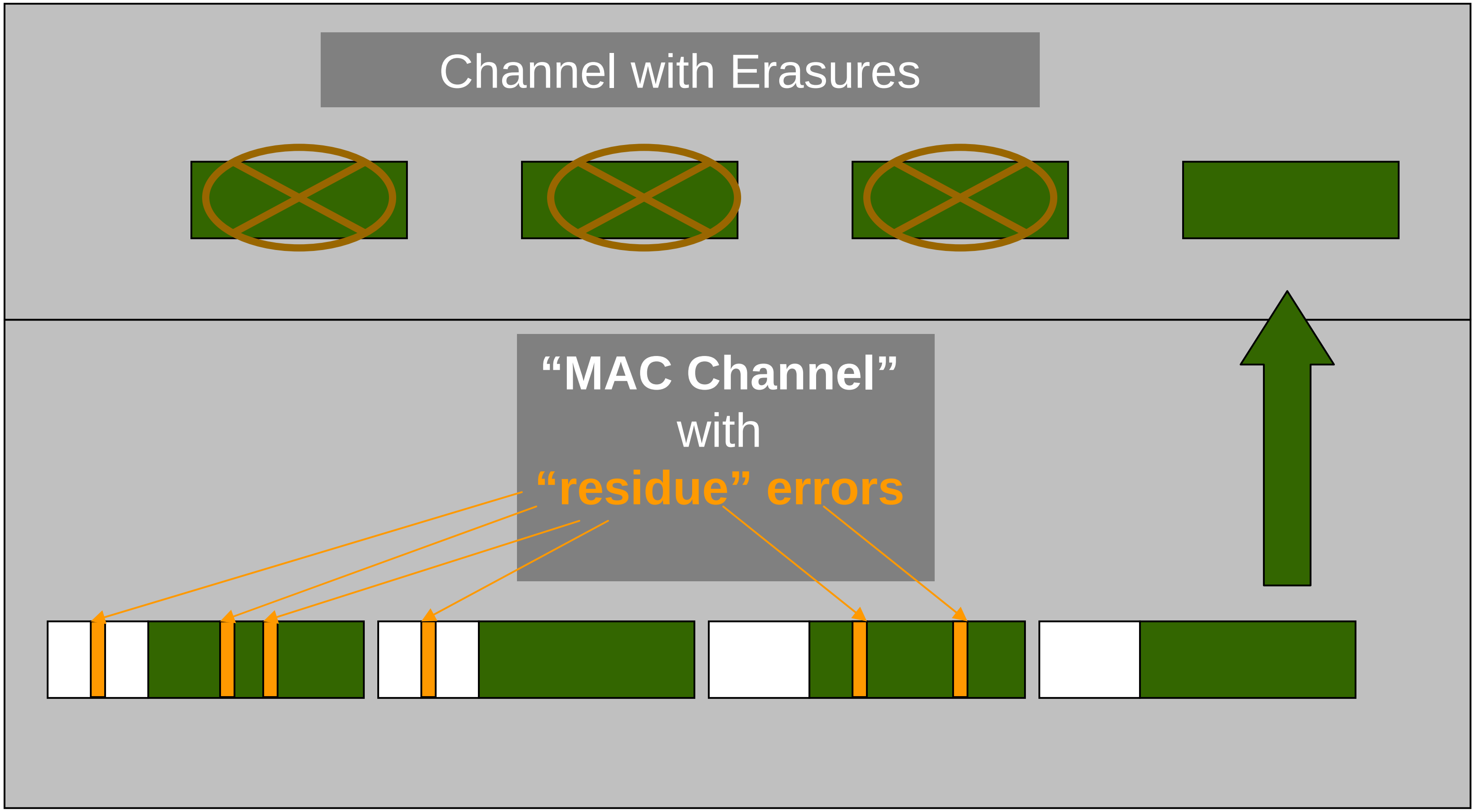
- Link quality varies significantly in wireless channels due to various types of interferences
  - Accurate channel capacity estimation/prediction using MAC layer above characterization is required

- Reducing packet losses due to deteriorated link conditions is required for rate-adaptive wireless video applications
  - Cross Layer Design with Side-Information (CLDS) protocols

Ideal Wireless World

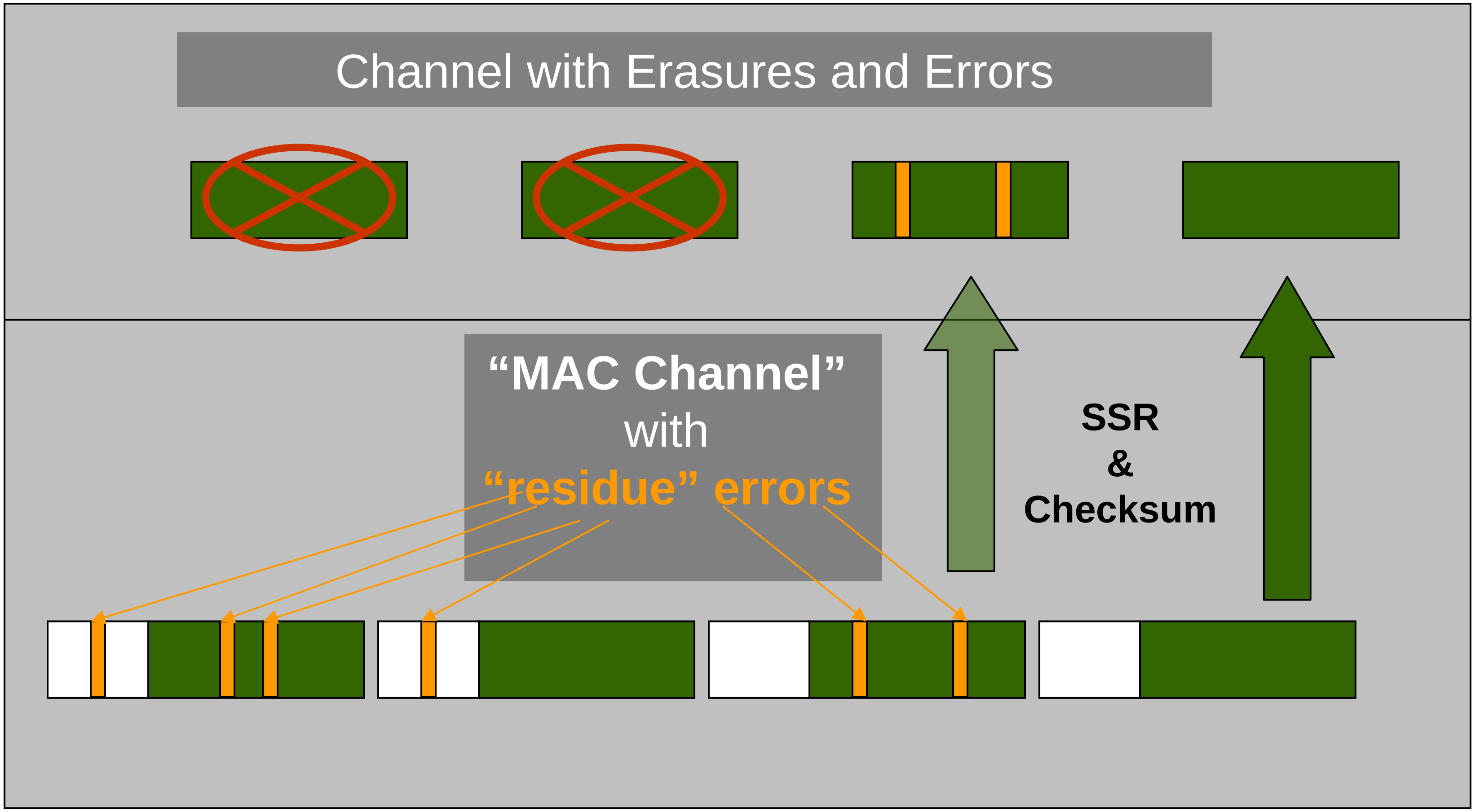


"Conventional" Wireless Protocol



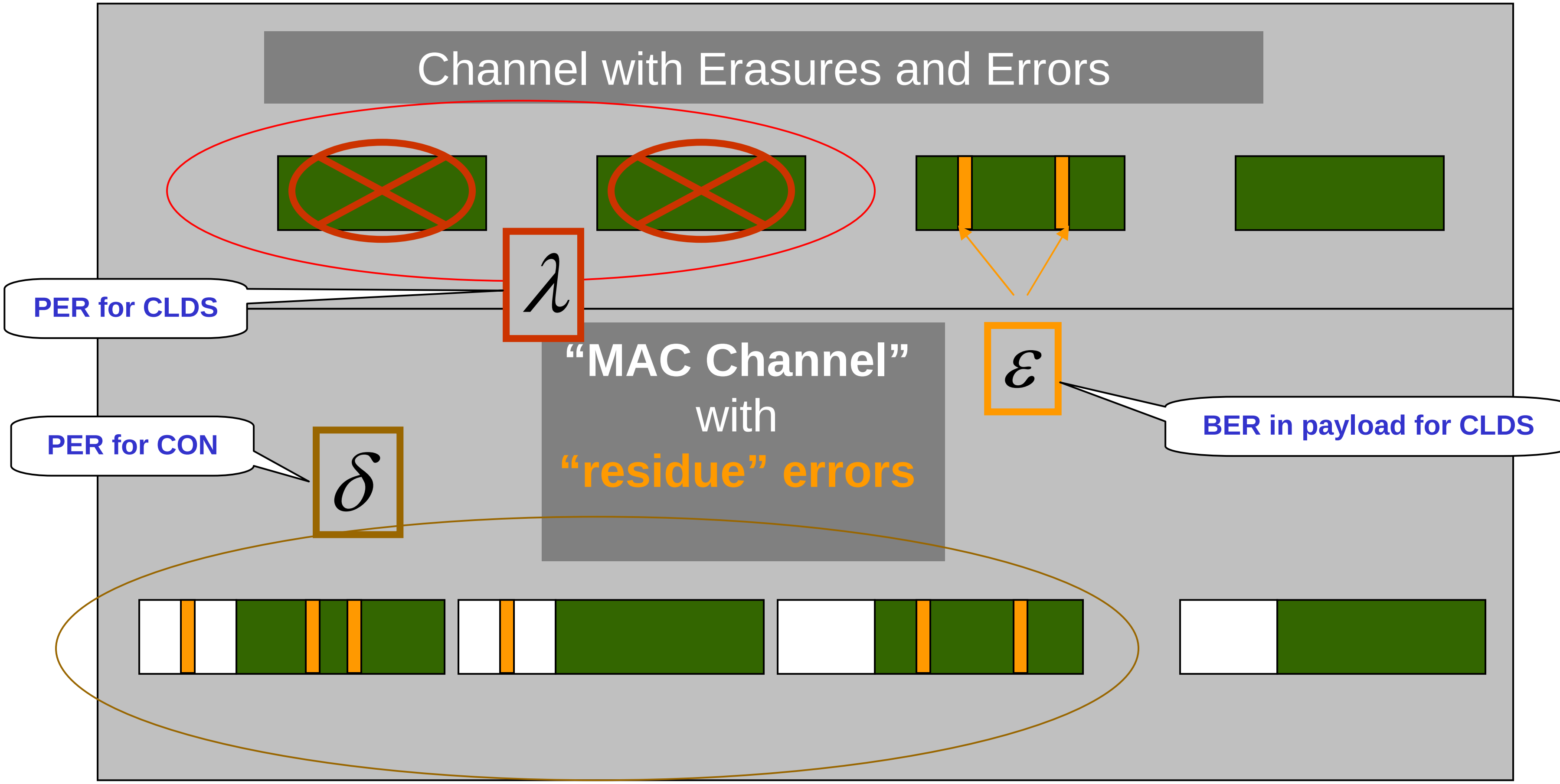
A residue error is an error that is not corrected by the physical layer, and hence it appears at the MAC layer

"Cross-layer" w/ Side-info Protocol



SSR (Signal to Silence Ratio):
- similar meaning of Signal to Noise Ratio or RSSI

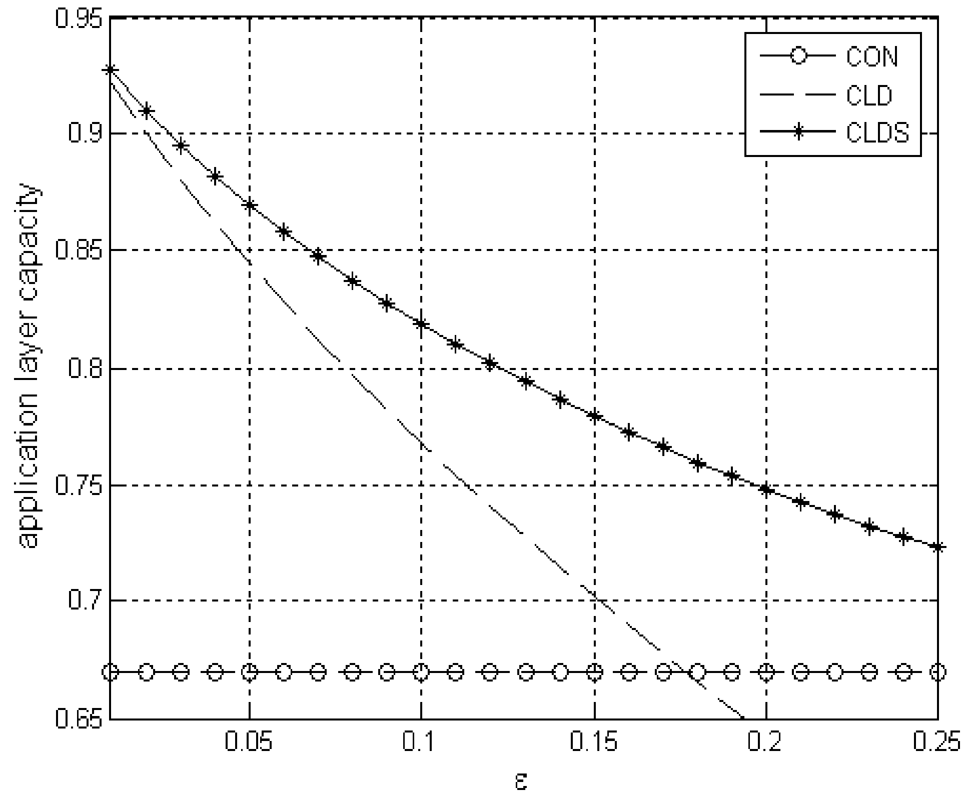
"Cross-layer" w/ Side-info Protocol



(Theoretical) Channel Evaluation

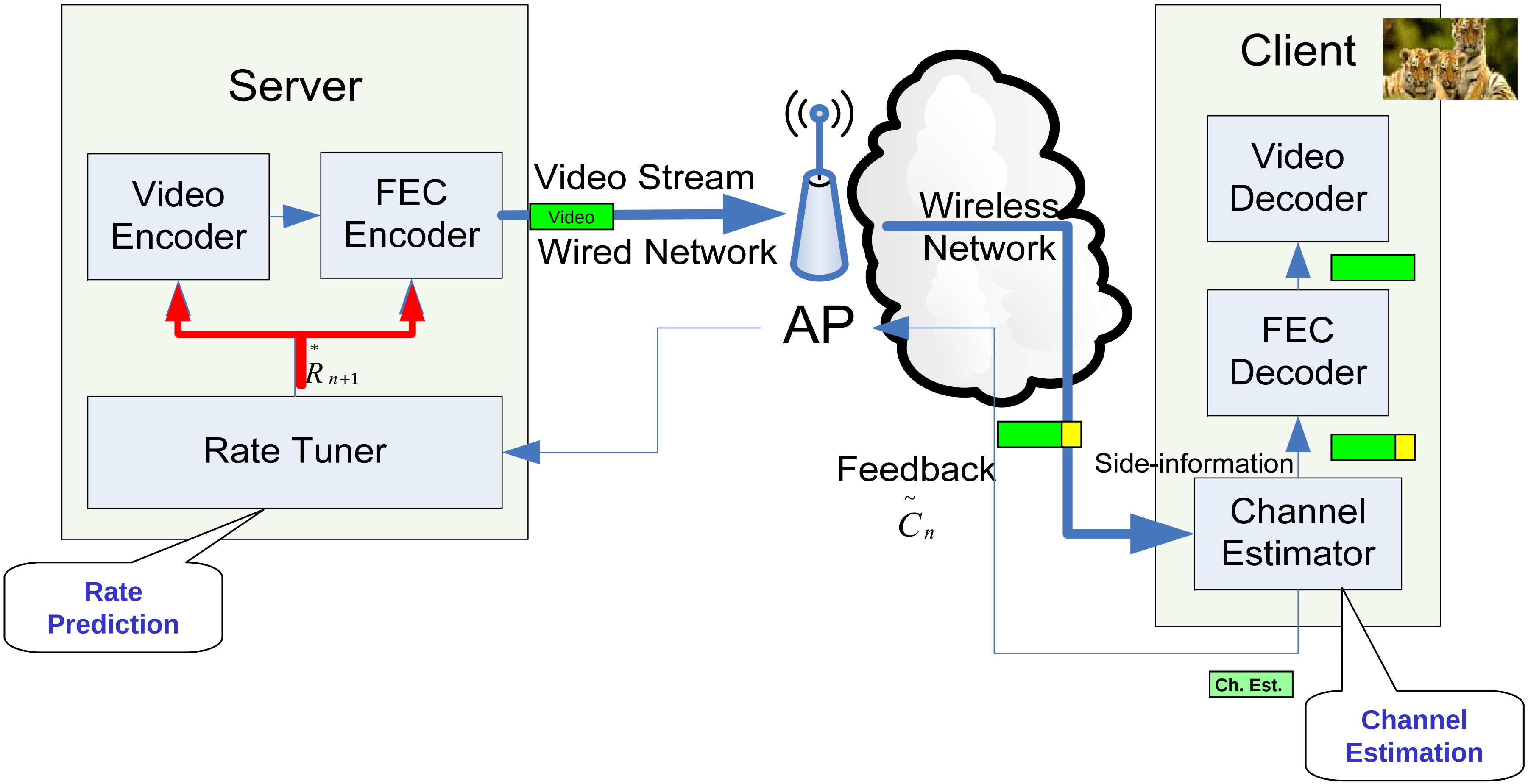
$\lambda = 0.05$

$\delta = 0.33$



[1]

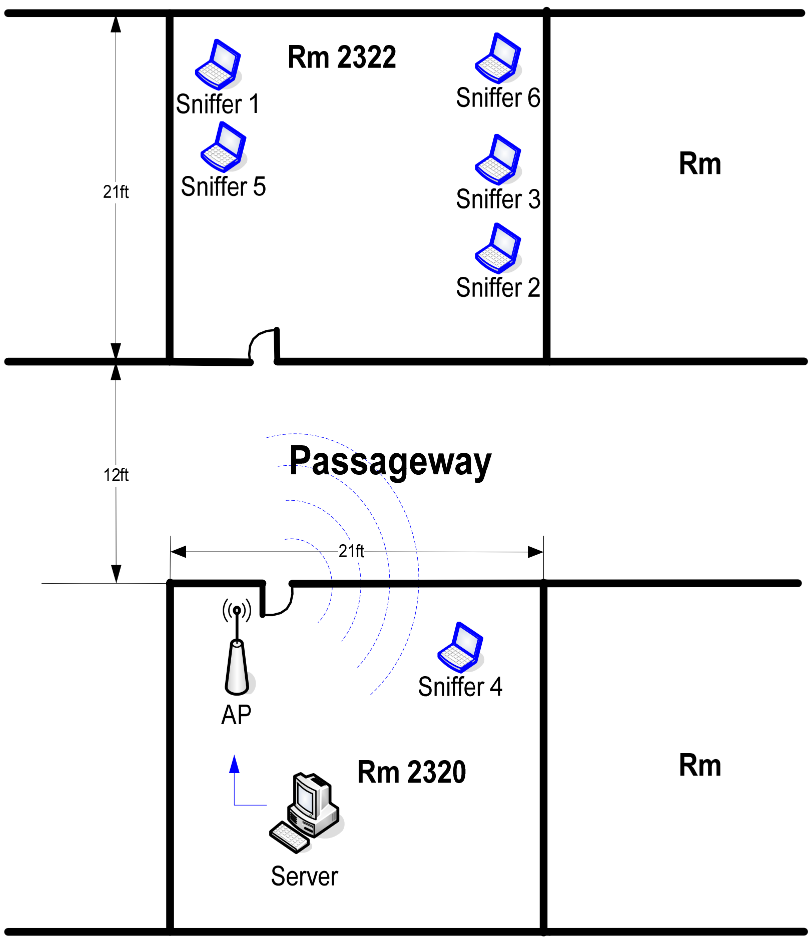
CLDS based Rate Adaptation Architecture



Our objective is to develop robust and practical rate prediction architecture to support QoS for wireless scalable video

WLAN Channel Analysis (1/5)

- Physical layer data rate at 2, 5.5, and 11 Mbps
- Packet transmit rate at 500, 750, 900, and 1024 Kbps
- 1 million packets with a payload of 1,000 bytes (each trace has about 1 GB of data and collected for about 4 and ½ hours at 500Kbps)



WLAN Channel Analysis (2/5)

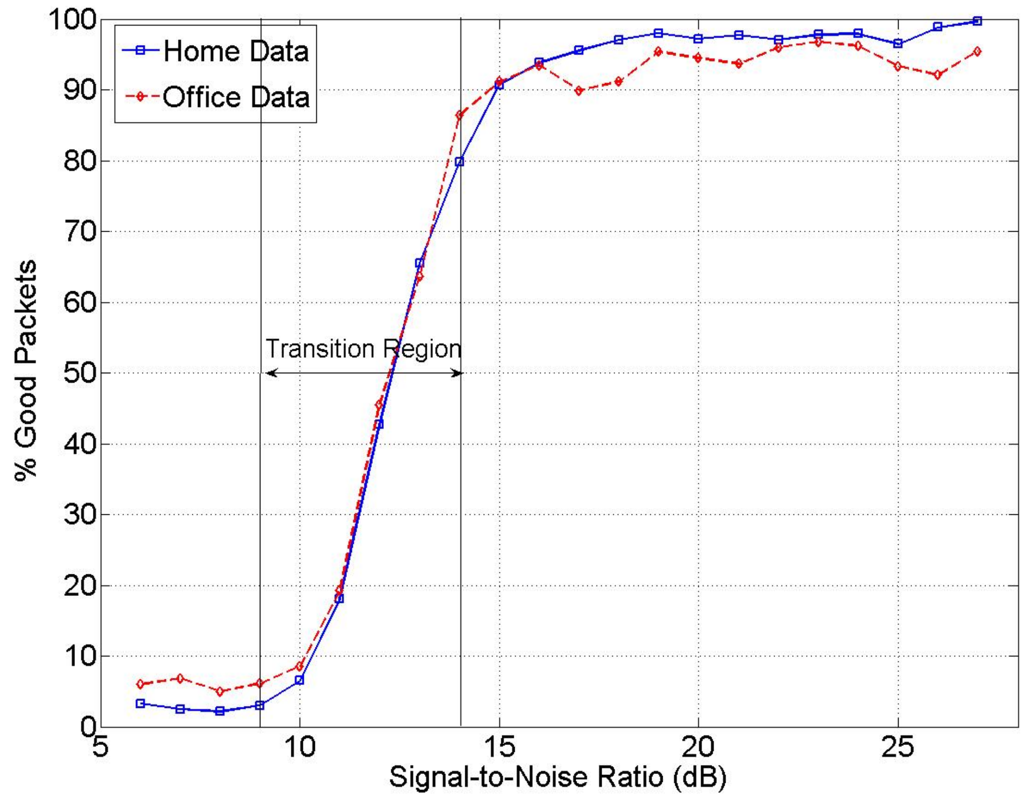
Statistics of Error Traces

Phy.rate (Mbps)	Avg.PER	Min. PER	Max. PER	Avg. SSR (dB)	Min. SSR (dB)	Max. SSR (dB)
2	5.97%	0.75%	14.31%	14.75	0	34
5.5	9.79%	0.61%	22.74%	15.27	0	32
11	39.5%	10.99%	77.83%	16.51	0	35

Error Statistics For Varying SSR Values at 11 Mbps

SSR (dB)	Average Packet-Error Rate	BER of all (error-free & corrupted) packets	BER of corrupted packets
5	0.7010	0.0253	0.0361
13	0.6248	0.0157	0.0251
20	0.2166	0.0048	0.0223
26	0.0384	0.0023	0.0591

WLAN Channel Analysis (3/5)



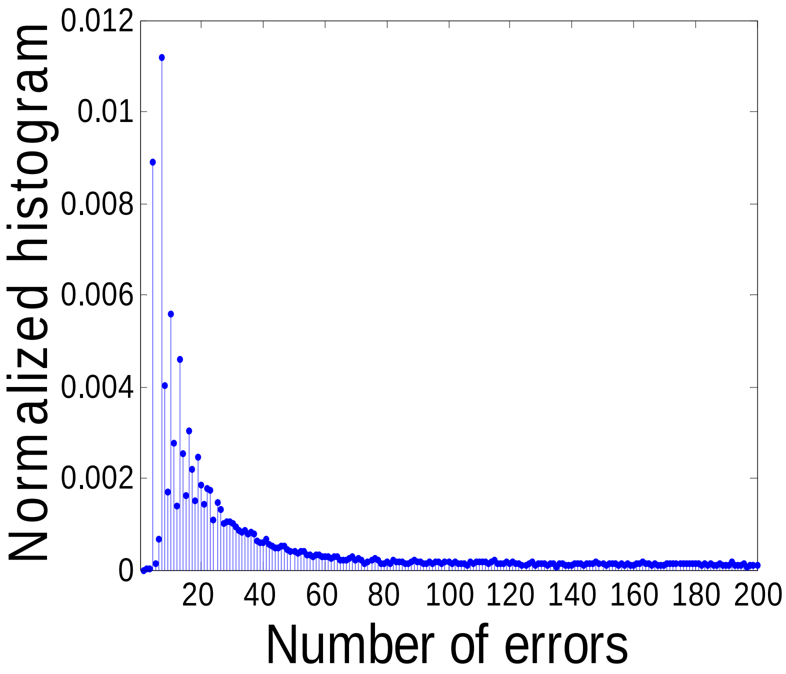
Bad Range:
SSR < 7dB,

Good Range:
>14dB

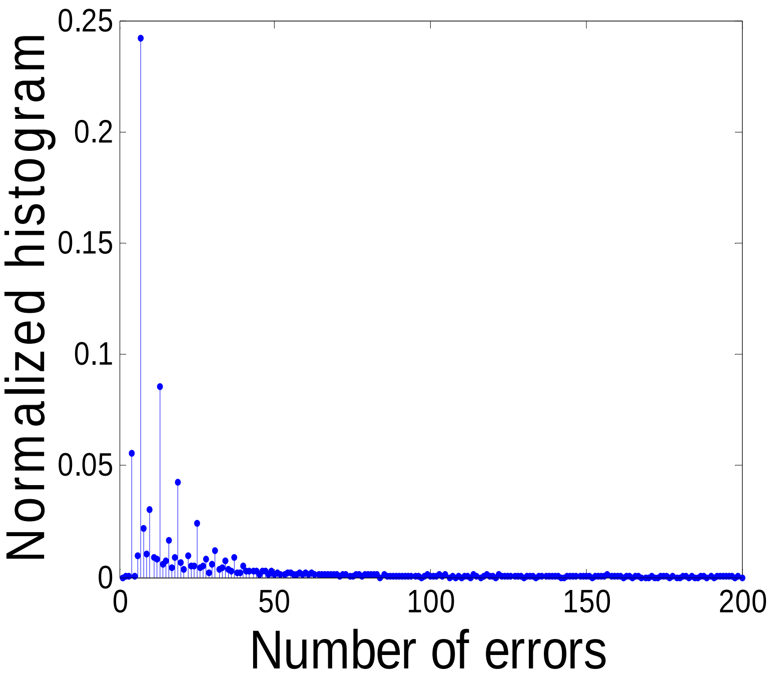
Transition Range
7 dB< SSR<14dB

WLAN Channel Analysis (4/5)

SSR vs. BER



SSR=5



SSR=26

SSR (Signal to Silence Ratio):
- similar meaning of Signal to Noise Ratio or RSSI

WLAN Channel Analysis (5/5)

- Most (error/error-free) packets have the SSR between 10 and 20 dB
- The higher physical layer data rate introduces more bit/packet errors
- A packet with higher SSR has less number of errors

➡ **SSR is very useful information**

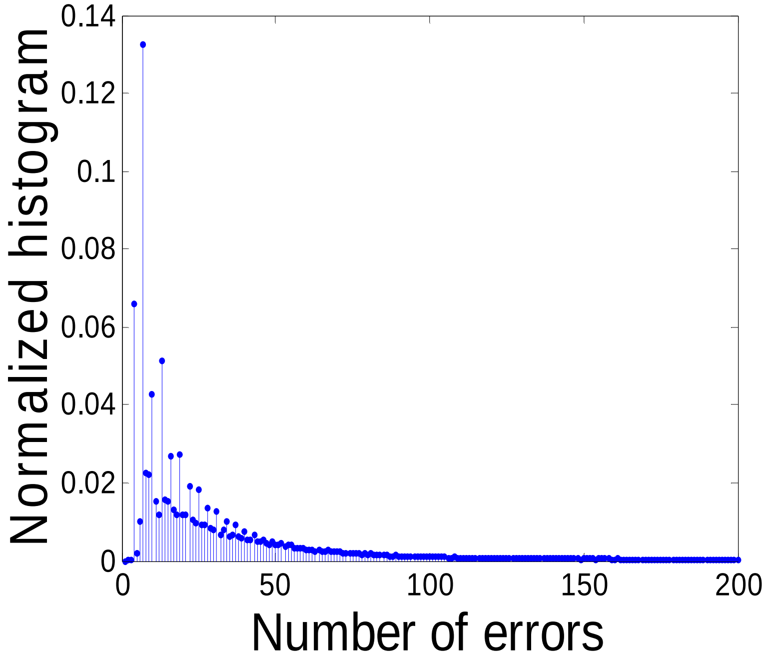
Observable ?

- Checksum & SSR are observable at the residual channel
  - Device driver has the above information, but does not utilize

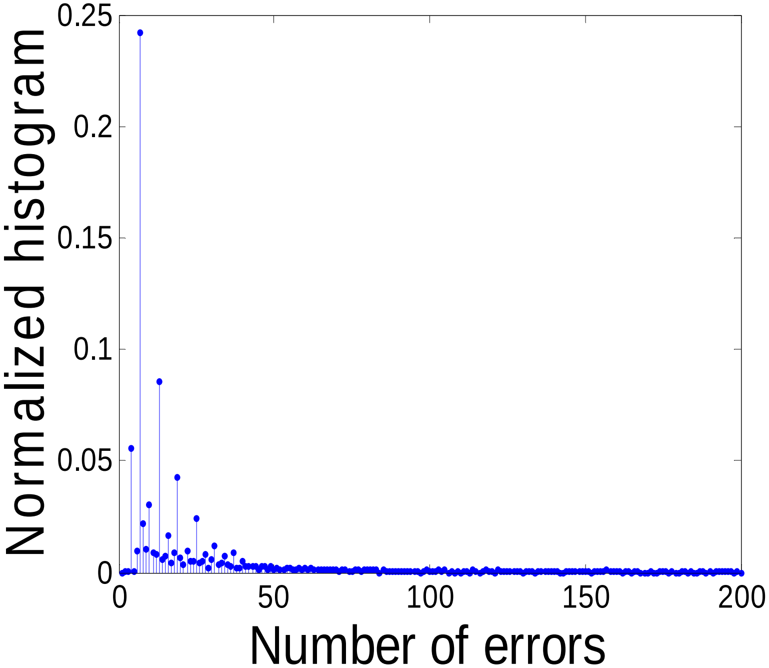
Channel Prediction w/ side-information

BER estimation

- SSR vs. BER

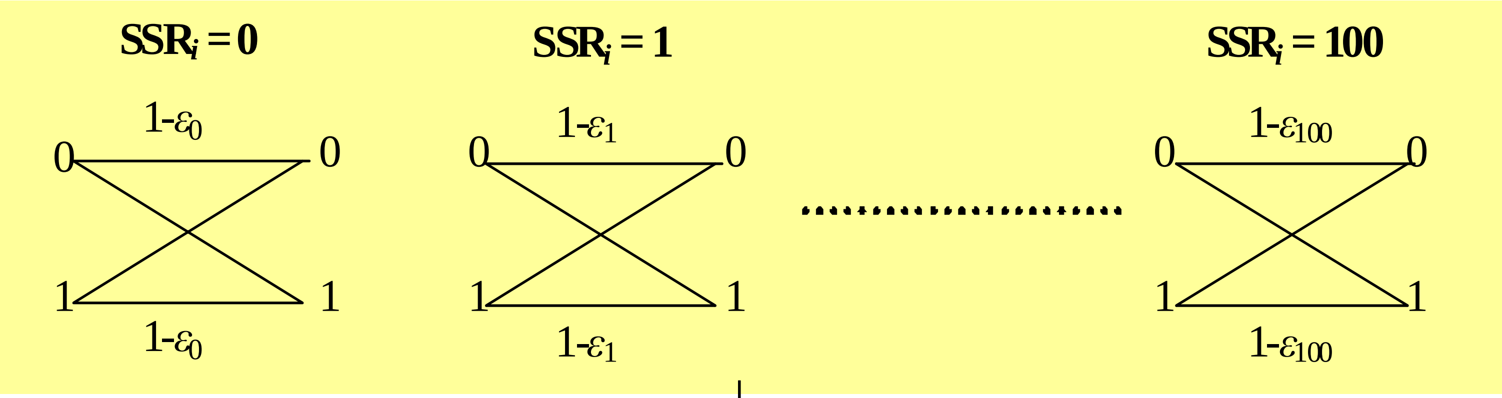


SSR=20



SSR=26

BER estimation



Estimated BER of i^{th} packet (crossover probability) using side-info

$$\tilde{\varepsilon}_i = E[\varepsilon \mid SSR_i, Z_i = 1]$$

Z_i : checksum of i^{th} packet

Channel Estimation

- We leverage $\tilde{\varepsilon}_i$ to estimate channel capacity for a rate adaptation period (or time-window)

$$\tilde{C}_n^{CLDS} = 1 - \frac{1}{m}\sum_{i=1}^{m} h_b(\tilde{\varepsilon}_i)$$

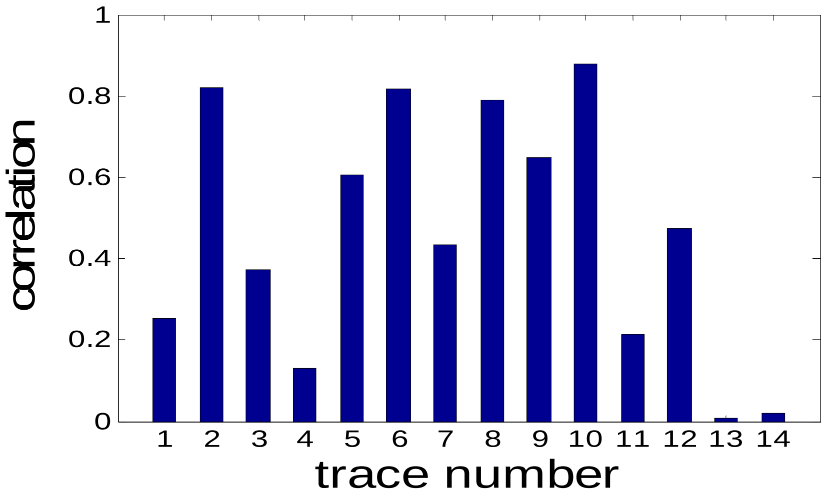
$$\tilde{C}_n^{CON} = 1 - \frac{1}{m}\sum_{i=1}^{m} Z_i = 1 - PER$$

n : Adaptation (time-window) index

m : The number of packets within a time-window

Channel Capacity Prediction

- Exploit the correlation (lag at 1) by using the channel capacity estimate of the current packet (or τ_i) as an estimate for the next packet's channel capacity: $\hat{C}_{n+1} = \tilde{C}_n$



$$\rho = \frac{E[C_n C_{n+1}] - E[C_n]E[C_{n+1}]}{\sqrt{\mathrm{var}[C_n] \cdot \mathrm{var}[C_{n+1}]}}$$

Note: the prediction performance is very similar to the optimum Yule-Walker predictor because the predictor in itself is based on noisy Estimates of the channel states

Channel Capacity Prediction

- This correlation can be taken advantage of to predict the channel capacity for the next time-window

$$\hat{C}_{n+1} = \tilde{C}_n$$

Channel prediction error process

$$e_{n+1} = C_n - \hat{C}_n \simeq \tilde{C}_n - \hat{C}_n = \hat{C}_{n+1} - \hat{C}_n$$

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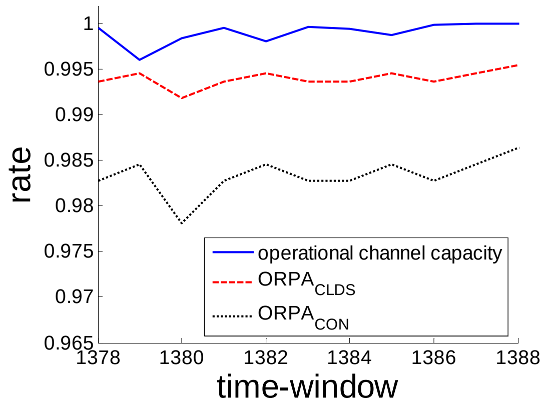
Capacity Prediction Results

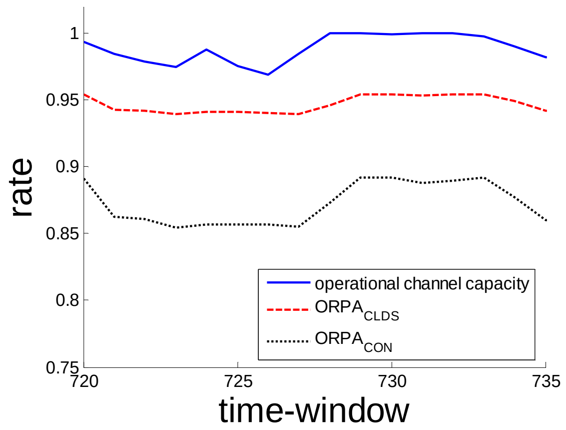
Average MSE Of Channel Capacity Prediction

Phy. data rate (Mbps)	Xmit rate (Kbps)	$ORPA_{CLDS}$ (Info.Bits²)	$ORPA_{CON}$ (Info.Bits²)
2	500	0.0004	0.0035
	750	0.00002	0.0002
	900	0.0002	0.0037
	1024	0.0002	0.0039
	Overall avg	**0.0002**	**0.0028**
5.5	500	0.0005	0.0053
	750	0.0007	0.0121
	900	0.0002	0.0019
	1024	0.0017	0.0172
	Overall avg	**0.0008**	**0.0091**
11	500	0.0014	0.0563
	750	0.0011	0.0168
	900	0.0033	0.1267
	1024	0.0056	0.2462
	Overall avg	**0.0029**	**0.1115**

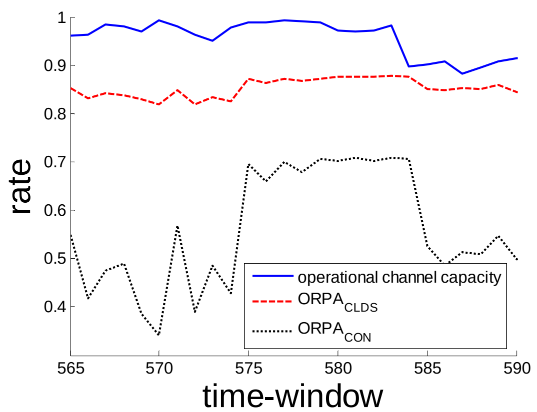
Rate Prediction/Tuning Results



(a) Phy.-2Mbps & Xmit rate-750Kbps



(b) Phy.-5.5Mbps & Xmit rate-750Kbps



(c) Phy.-10Mbps & Xmit rate-1Mbps

The optimally allocated channel capacities (or channel coding rates) based on predictions

Rate Tuning Results

Phy (Mbps)	Pkt Xmit Rate (Kbps)	Actual Chan. (PSNR (dB))	$ORPA_{CLDS}$ (dB)	$ORPA_{CON}$ (dB)
2	500	28.96	27.67	27.81
	750	31.02	30.74	30.78
	900	31.93	31.51	31.25
	1024	32.52	32.43	32.31
	avg	**31.11**	**30.59**	**30.53**
5.5	500	29.00	27.92	28.23
	750	30.88	29.39	29.84
	900	31.90	30.78	29.98
	1024	32.47	32.38	30.95
	avg	**31.06**	**30.11**	**29.75**
11	500	29.00	27.59	25.22
	750	30.88	29.53	30.18
	900	31.78	30.67	22.73
	1024	31.99	30.12	15.01
	avg	**30.91**	**29.47**	**23.28**

Prediction Performance (In Terms Of Overall Video Quality) After The Optimal Rate Tuning

Conclusion

- It clearly shows that we can achieve robust rate adaptation using Cross Layer Design w/ Side-information (CLDS) protocol
  - Packet-level side-information such as SSR (or RSSI) is very useful information to estimate/predict channel conditions (or rates)

- Related Requirement (CLO-03)
  - MMT shall support optimization of QoS/QoE of multimedia applications by utilizing information (SSR, etc) from underlying layers

Thank you !