UWB Modulation Design and Joint-Cross Layer QoS Wireless Content Delivery

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Outline

- Why is the problem important?
- What is our approach?

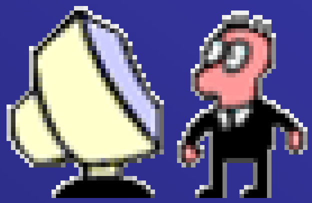
1. UWB Modulation Design
2. Cross-layer QoS Wireless Content Delivery

- Conclusions

Content

Bi-phase UWB Modulation

Cross-layer QoS Content Delivery



History of Impulse Radio

- In 1893, Heinrich Hertz used a spark discharge to generate electromagnetic waves for his experiments – that is probably the first impulse radio

Heinrich Hertz

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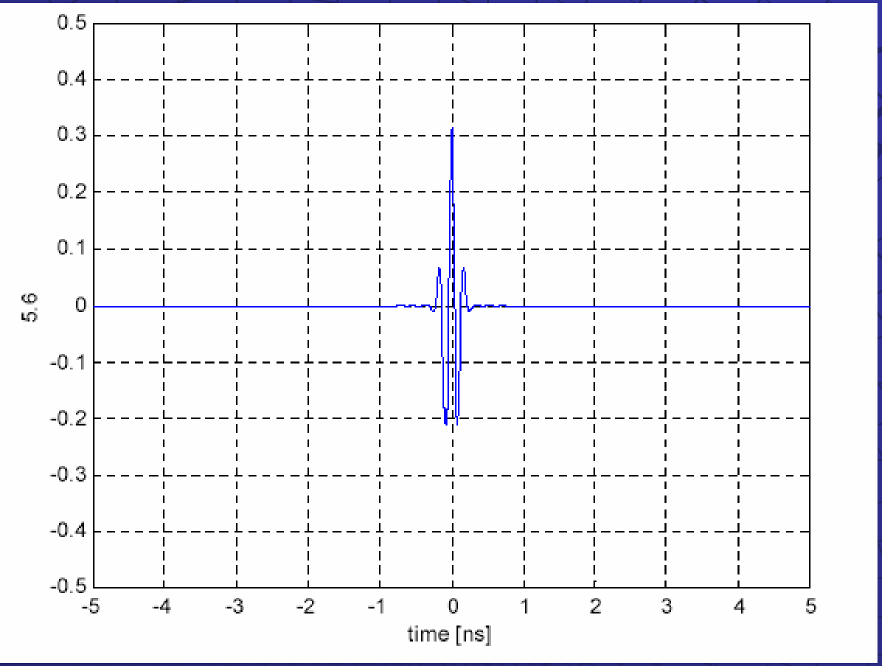
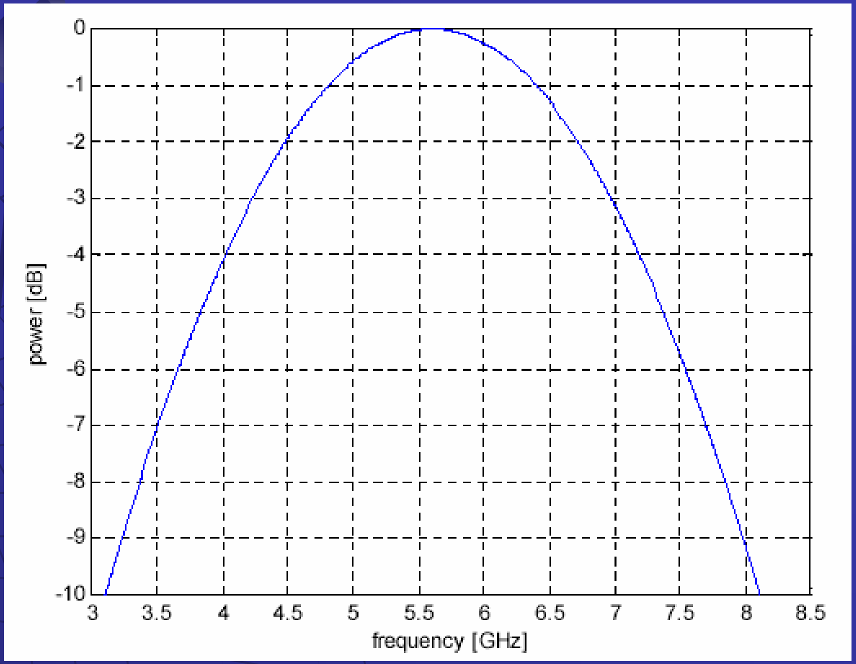
Ultra Wideband

- UWB uses a series of short impulses with spectrum spreading from near DC to a few Gigahertzes,





- High data throughput -- providing *gigabit* wireless connection.

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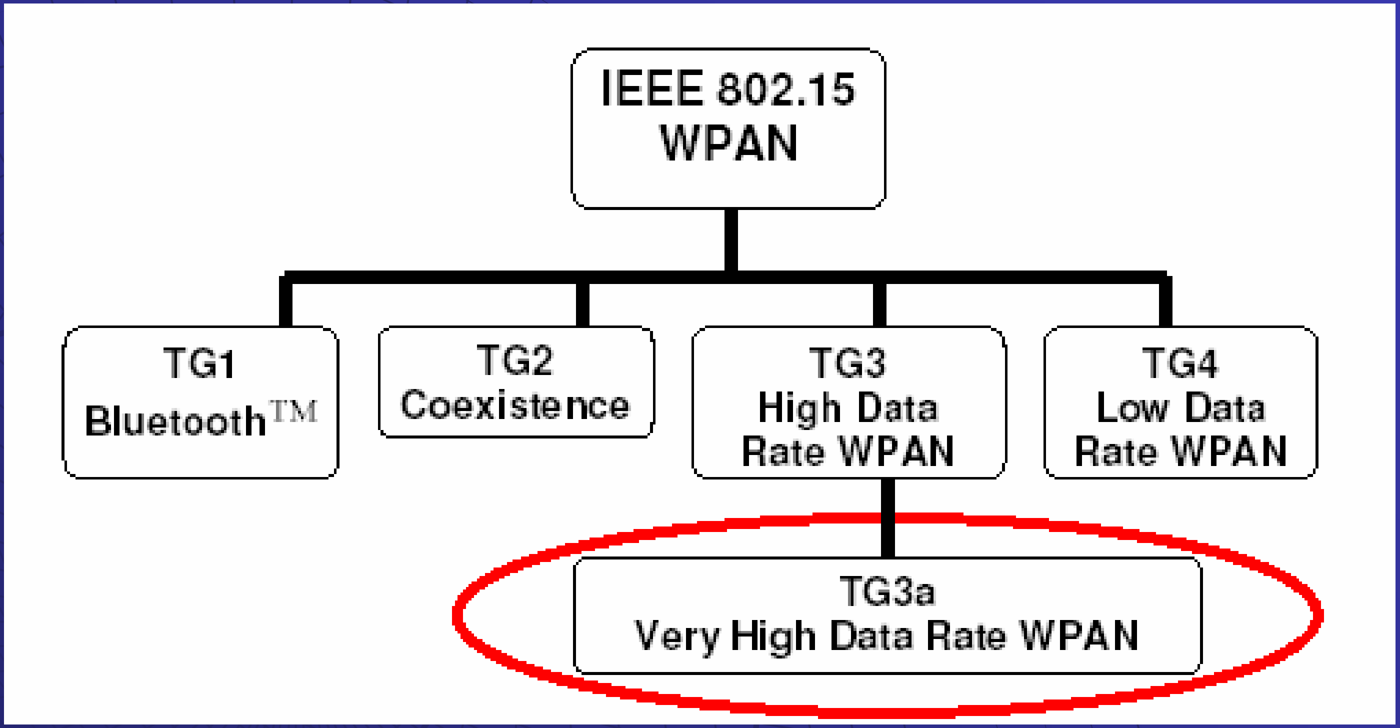
Current Standardization

- Activities in IEEE 802.15



- IEEE 802.15 is a subset of IEEE 802.11a (<54Mb/s).
- IEEE 802.15.3 targets to deliver data rate at Gbs/s

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Different UWB Approaches

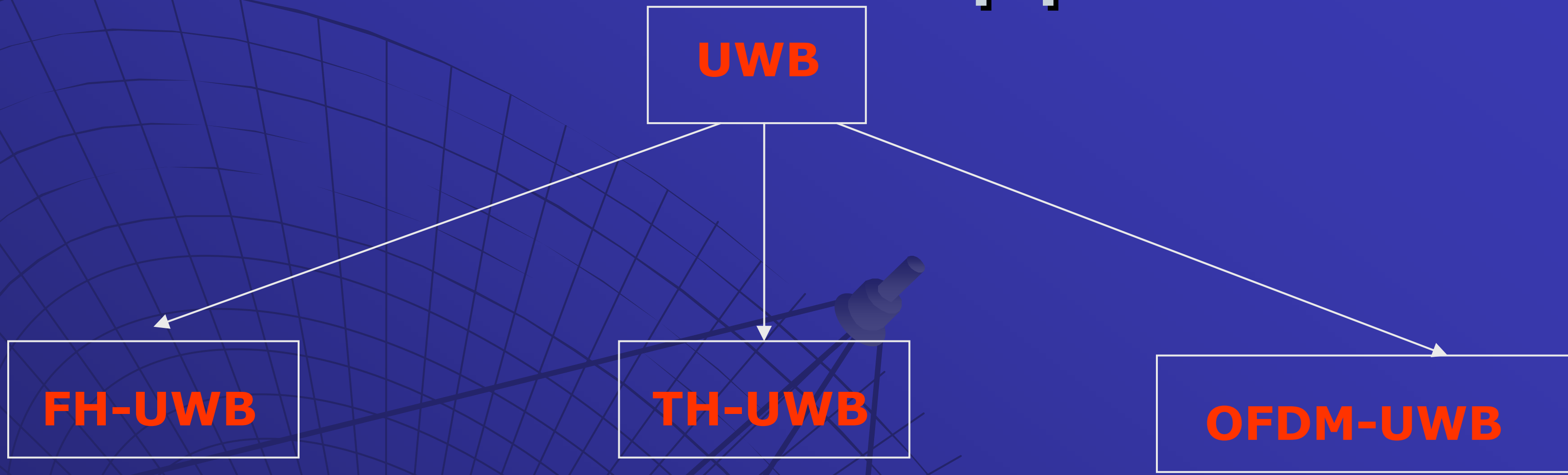
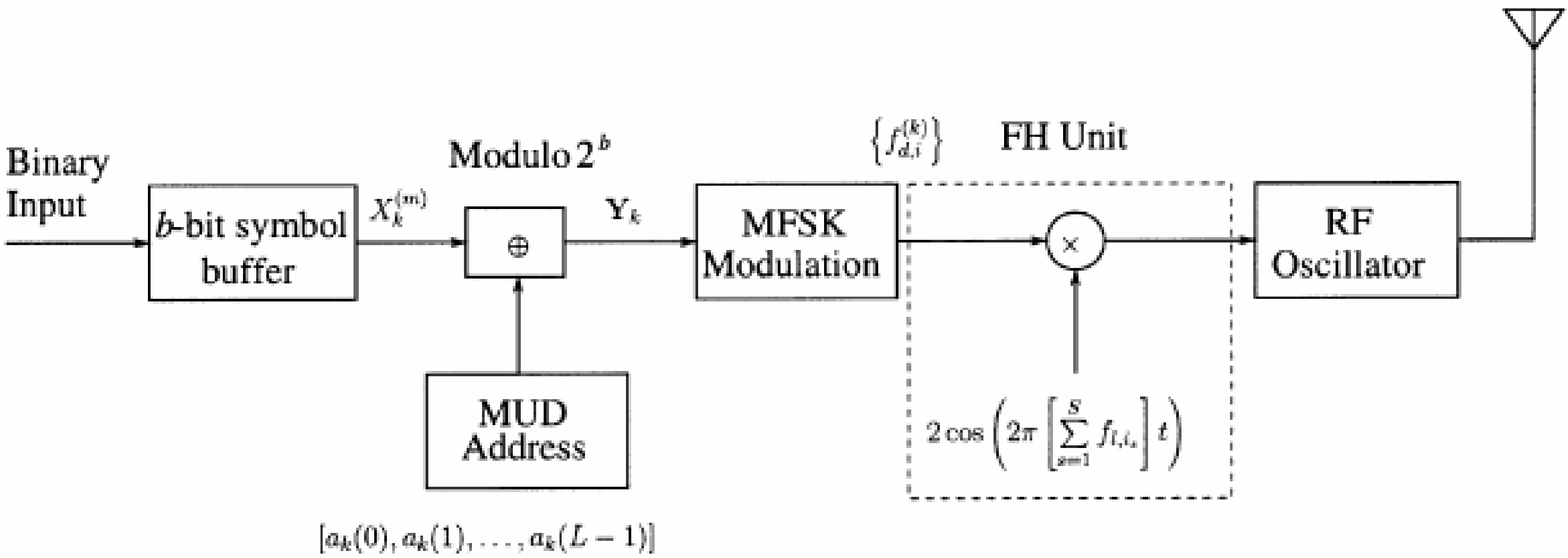


Table 3. Single-band and multiband comparison.		
Parameter	Single band	Multiband
Number of bands	1	15
Bandwidth/band	7,500 MHz	500 MHz
Signal rate/band	200 MHz	13.4 MHz
Thermal noise	–75 dBm	–87 dBm
Total signal power	+16 dBm	+4 dBm

IEEE microwave magazine, June 2003

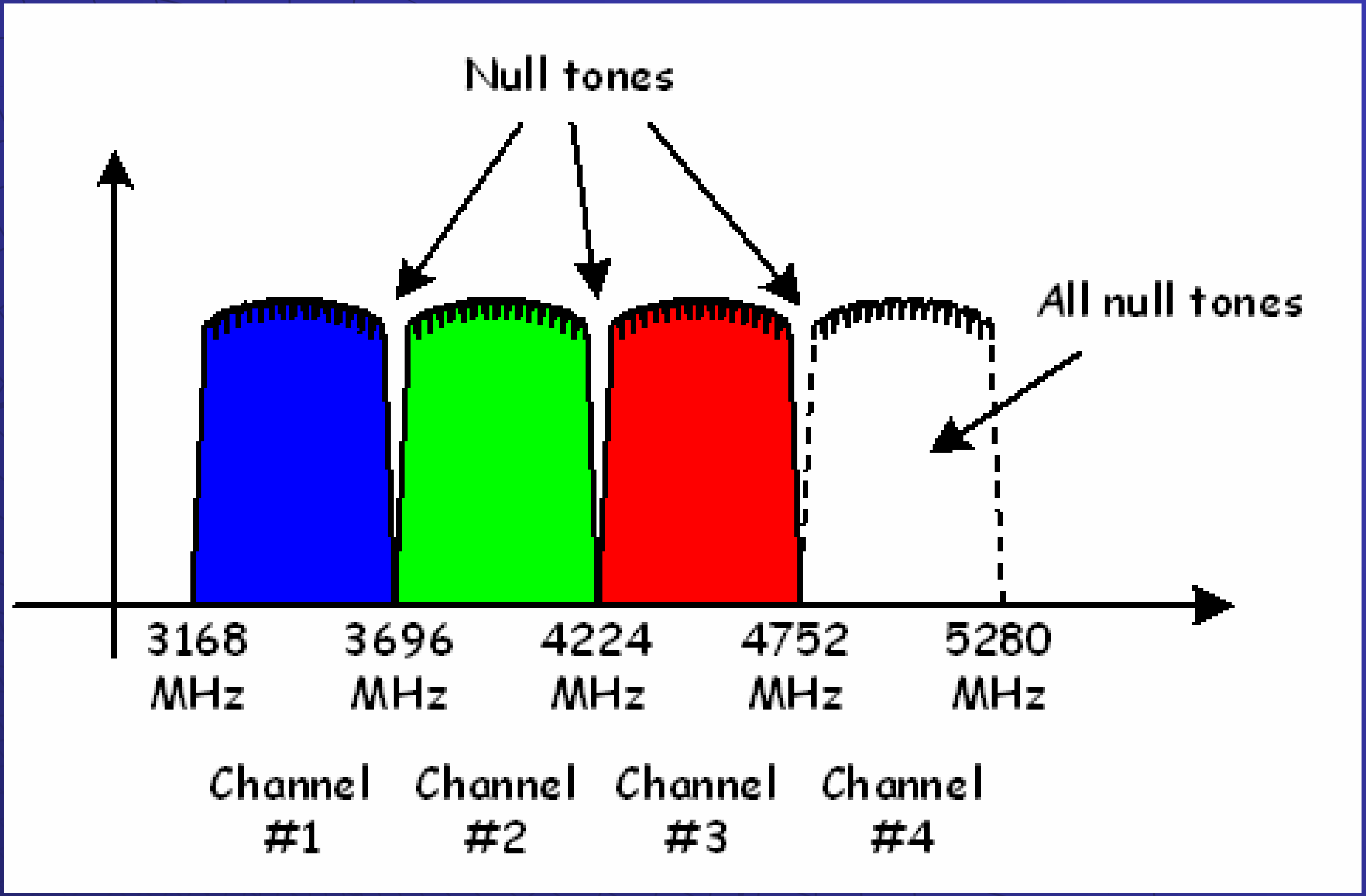
FH-UWB



(a)

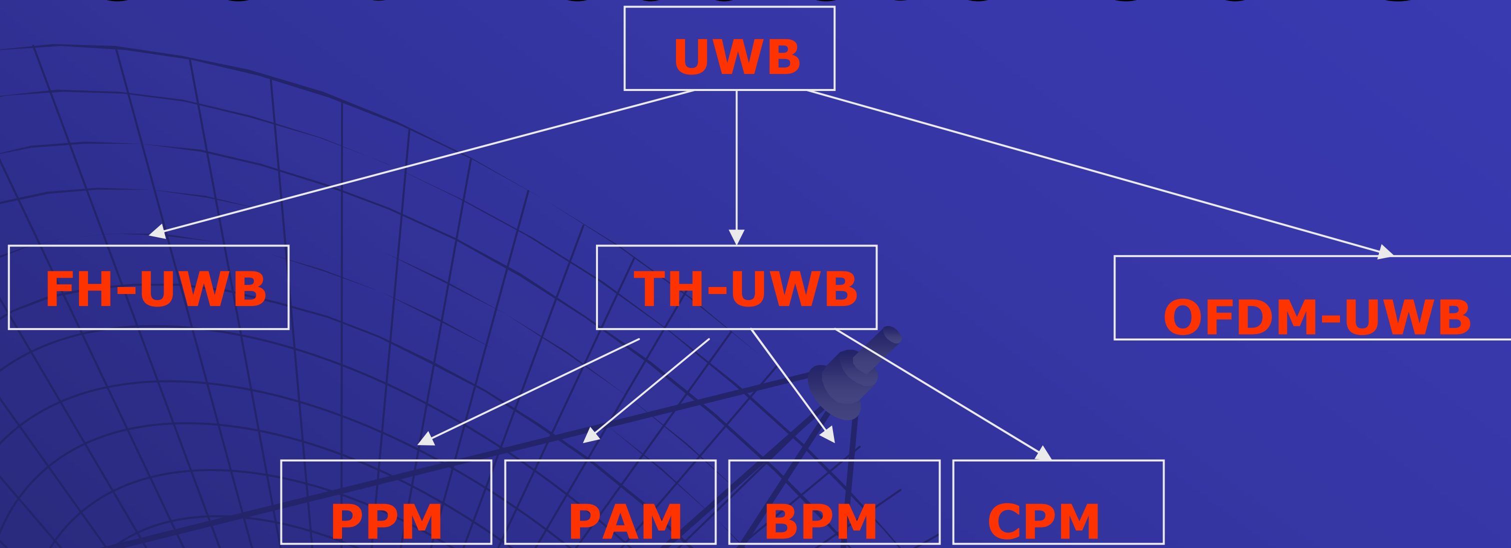
Lie-Liang Yang, Lajos Hanzo “Residue Number System Assisted Fast Frequency-Hopped Synchronous Ultra-Wideband Spread-Spectrum Multiple-Access: A Design Alternative to Impulse Radio”, IEEE JSAC, Dec 2002

Multiband UWB



Anuj Batra, Jaiganesh Balakrishnan, et. al “Time-Frequency Interleaved Orthogonal Frequency Division Multiplexing”, IEEE 802.15.3a proposal 2002

Different Modulations of UWB



Moe's PPM (Pulse Position Modulation): δd

Moe Win, IEEE Trans. on Communication, 2000

BPM (Bi-Phase Modulation): w_{tr}

Pseudo-random sequence: C_j

Taylor's PAM (Amplitude modulation)

M. Ho, L. Taylor, *IEEE Int. Conf. Consumer Electronics*, 2001

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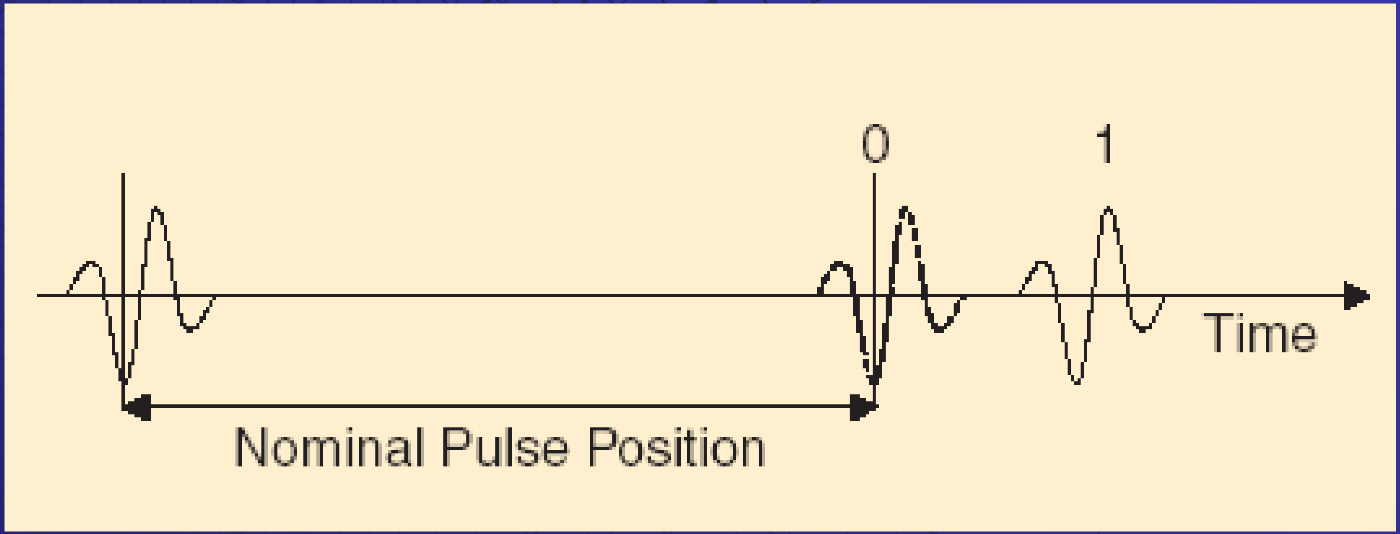
TH-PPM UWB

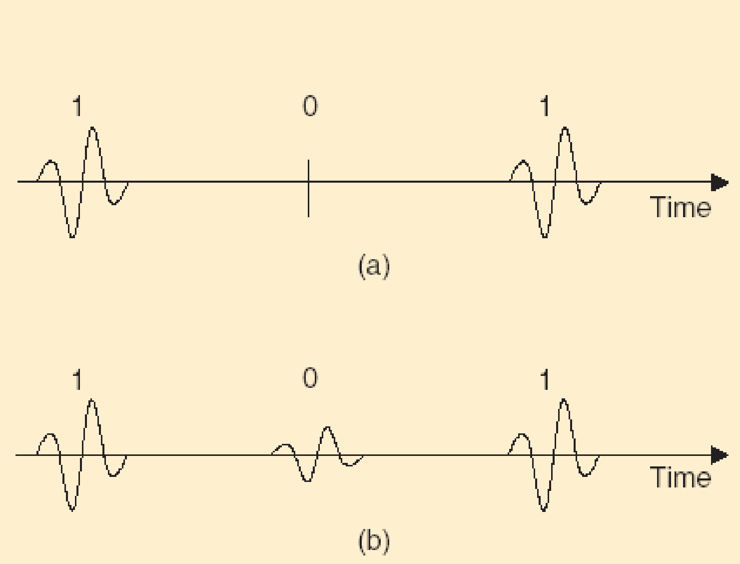
- PPM is based on the principle of encoding information with two or more positions in time, referred to the nominal pulse position.
- The time between nominal position is typically at the *ns* scale to avoid interference between impulses.



Moe Z. Win, Robert A. Scholtz , IEEE Trans. on Comm, June 2000

TH-PAM UWB

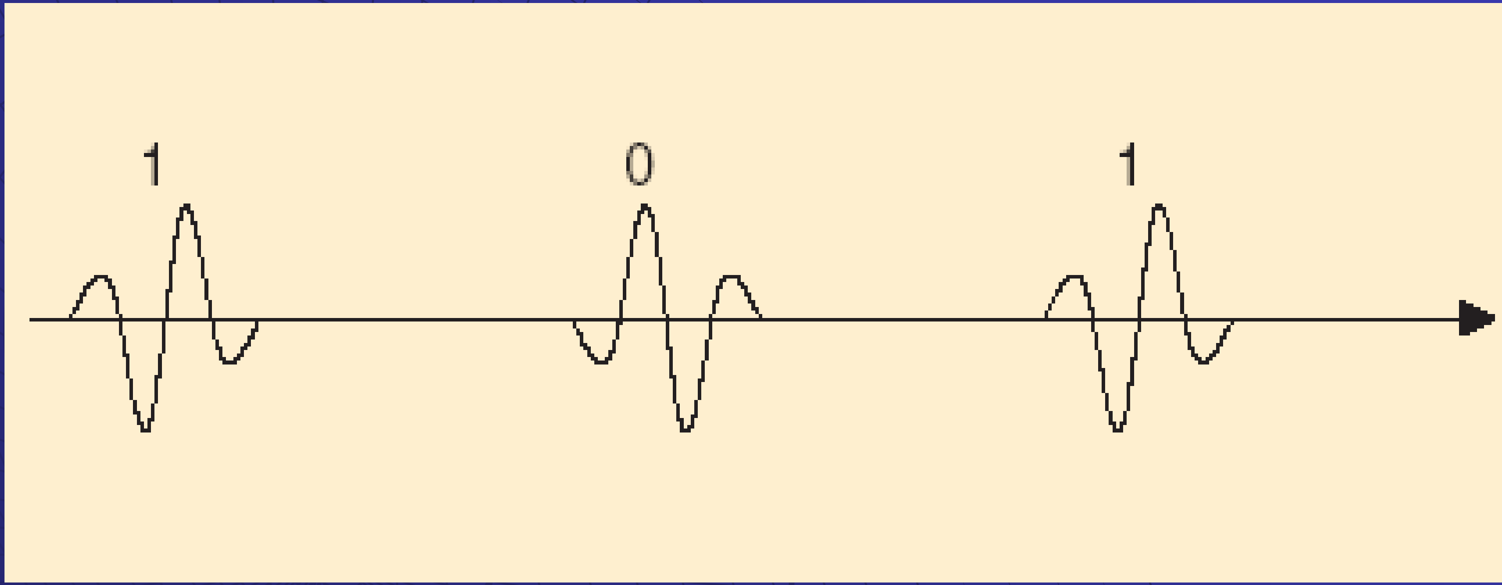
- PAM is based on the principle of encoding information with the amplitude of impulses
- More amplitude levels can be used to encode more than one bit per symbol.



M. Ho, L. Taylor, and G.R. Aiello," UWB architecture for wireless video networking," in *Proc. IEEE Int. Conf. Consumer Electronics*, 2001, pp. 18-19.

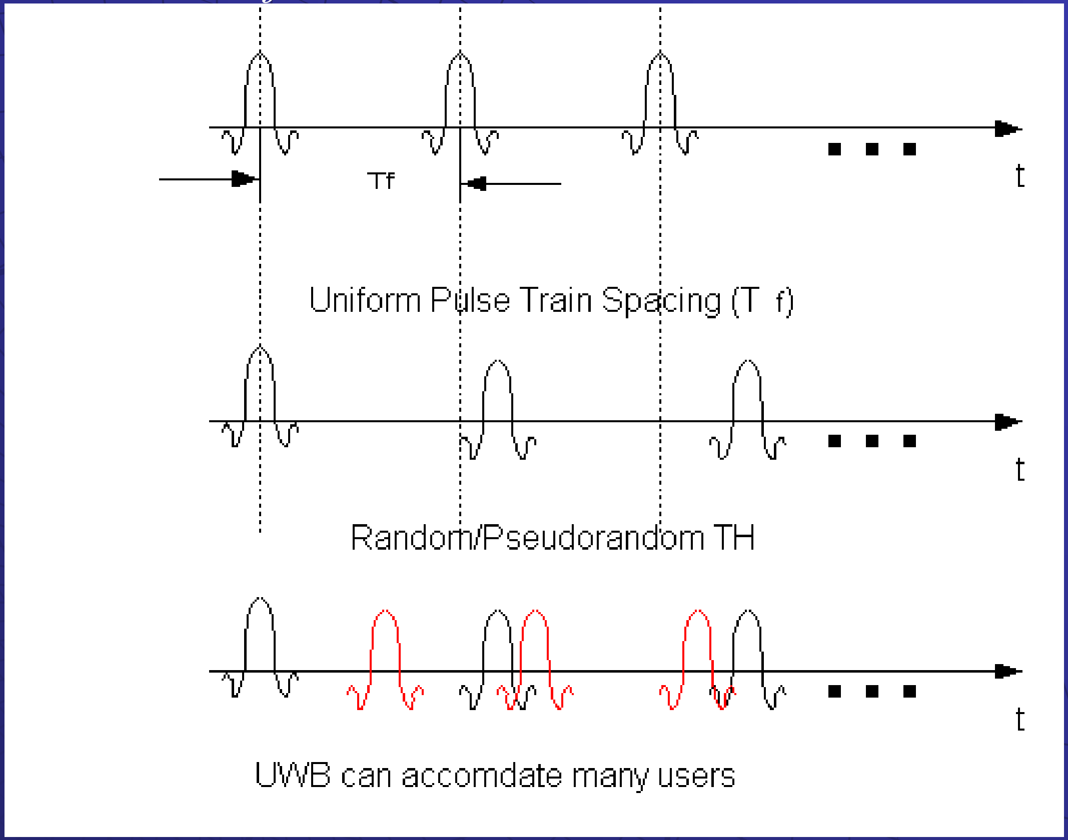
TH-BPSK UWB

- Information is encoded with the polarity of the impulses



Introduction to UWB

$$S_{tr}^{(k)}(u, t^{(k)}) = \sum_{j=0}^{N_s} w_{tr}\left(t_k - jT_f - c_j^{(k)}(u)T_C - \delta d_j^{(k)}(u)\right)$$



t_f: 100ns, T_c: 1.5ns, T_m: 0.7ns, δ: 0.156ns

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We can view different users as interferences

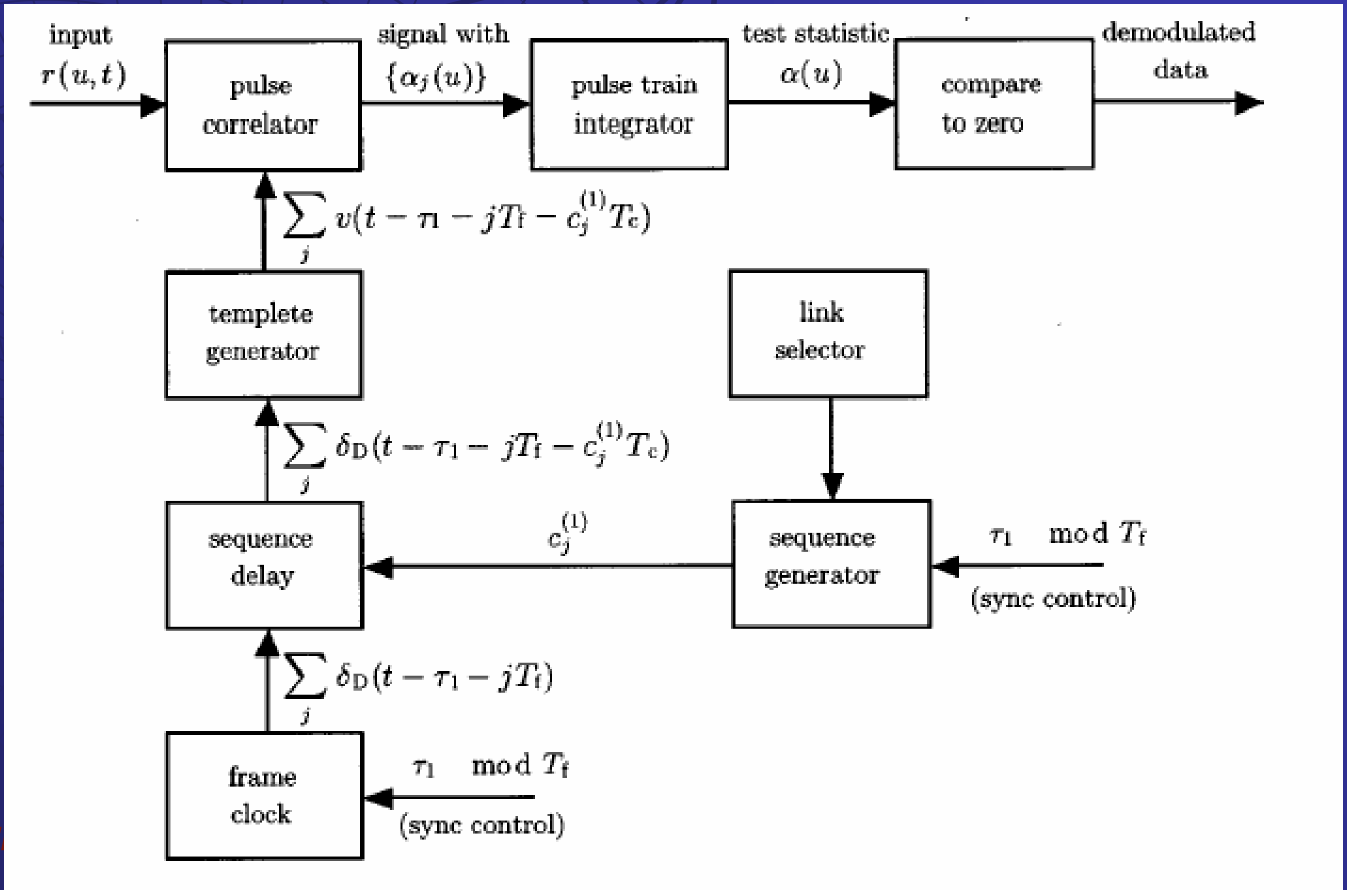
Receiver Design

$$d_j = \int_{T_{Syn,j}}^{T_{Syn,j}+T_f} \mathbb{R}_{Rec,Sym}(u, T - t_j)\cdot v(T)\, dT$$

Decision

Statistics

$$D = \sum_{j=0}^{N_S - 1} d_j \qquad B^{(k)}(u) = \begin{cases} 0 & when \quad D > 0 \\ 1 & when \quad D < 0 \end{cases}$$



Ultra Wideband

- Time jittering (0.1ns) can significantly lower BER

100 Multi-Users

200 Multi-Users

UWB approach

100 Multi-Users

200 Multi-Users

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We can view different users as interferences

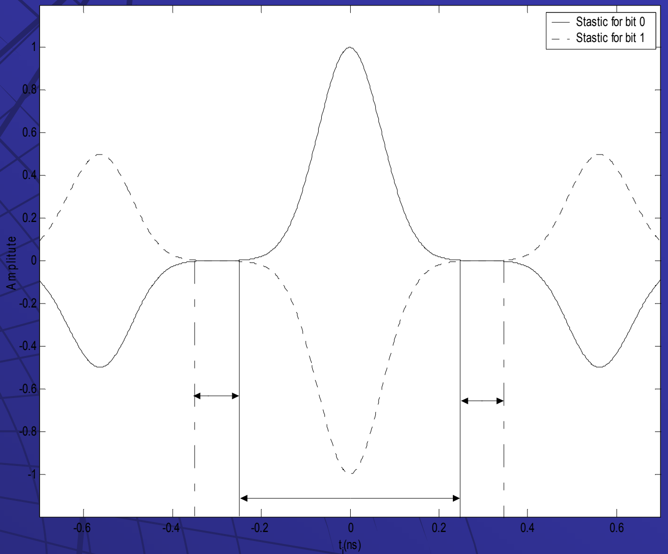
Solutions

1. *Increase the impulse parameter* τ_m

-- increase the impulse duration and sacrifice the system throughput.

-- UWB bandwidth also decreases

2. *Bi-phase Modulation*



$$S_{tr}^{(k)}(u, t^{(k)}) = \sum_{j=0}^{N_s} (1-2D^{(k)}(u)).w_{tr}\left(t_k - jT_f - c_j^{(k)}(u)T_C\right)$$

Timing Jitter-robust UWB

Challenges lie in waveform design

-- Orthogonal waveforms that can tolerance maximum timing jittering.

With the same bandwidth !!

Proposed Design

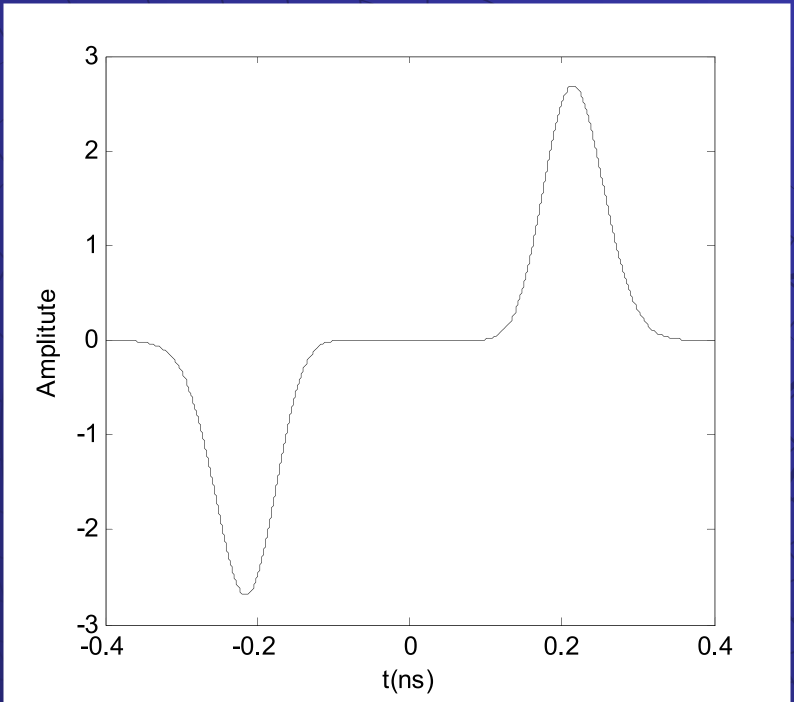
Proposed waveform:

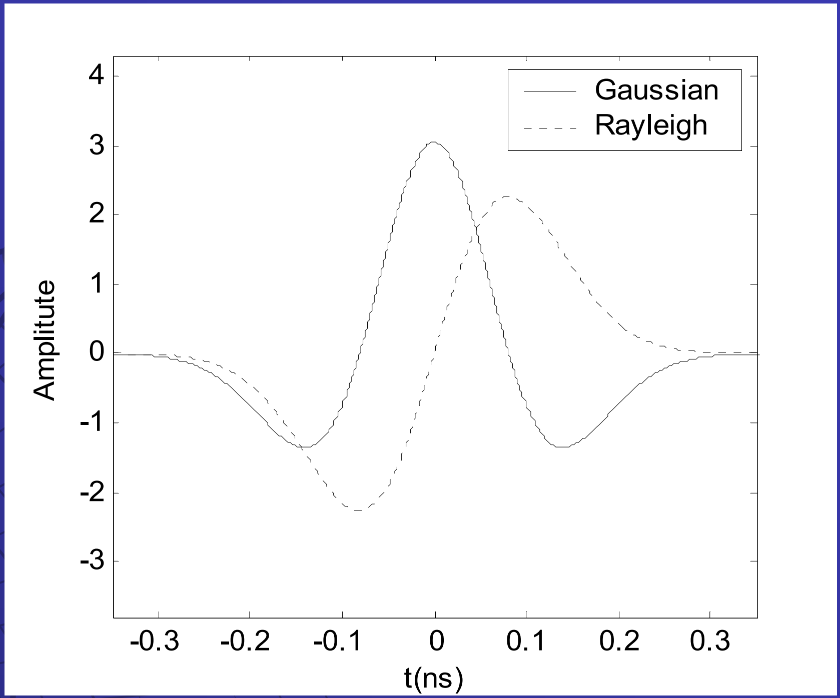
$$H(t) = A_H \left(t^{\mathbb{N}} \cdot \exp[-2\pi(\frac{t}{\tau_m})^2] \right)$$

where N is the order of the monocycle;

and
$$\int_{-\infty}^{\infty} H(t)\, dt = 0$$

Proposed Design





Proposed waveform

$$H(t) = A_H\left(t^{\mathbb{N}} \cdot \exp[-2\pi(\frac{t}{\tau_m})^2] \right)$$

Gaussian:

$$G(t) = A_G\left(1 - 4\pi(\frac{t}{\tau_m})^2 \cdot \exp[-2\pi(\frac{t}{\tau_m})^2] \right)$$

Rayleigh:

$$R(t) = A_R\left(\frac{t}{{\tau_m}^2} \cdot \exp[-2\pi(\frac{t}{\tau_m})^2] \right)$$

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Analyze the Timing-jittering Performance

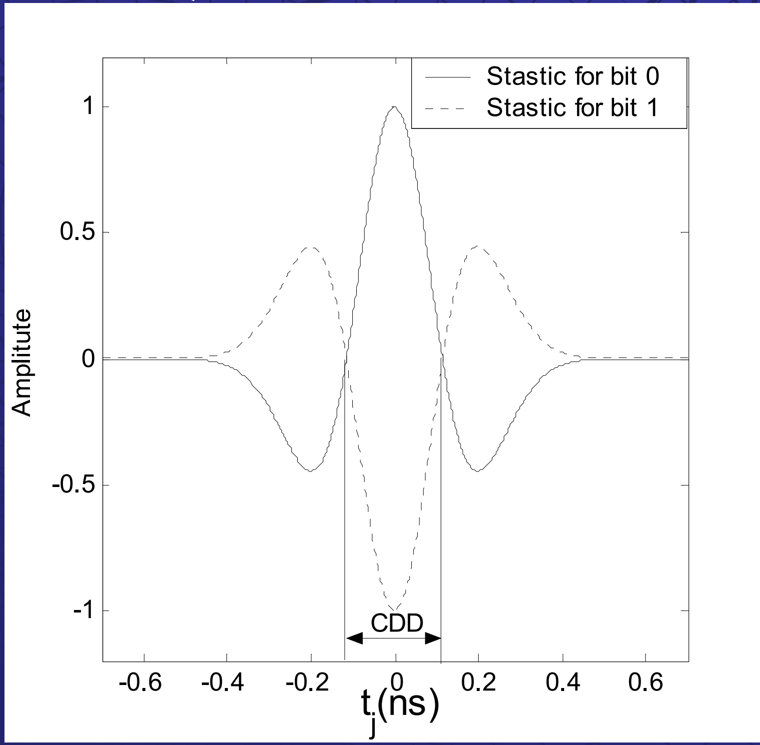
Timing-jittering tolerance determined by the decision statistics

$$d_j(t_j) = \int_{T_{Syn,j}}^{T_{Syn,j}+T_f} \mathbb{R}_{Rec,Sym}(u, T - t_j) \cdot v(T)\, dT$$

here t_j is the timing-jittering

Decision Statistics (Rayleigh)

$$d_{j,R} = \frac{A_R A'_R}{\tau_m^4} \sum_{k=1}^{2} \left(\begin{array}{l} \exp\left(2xt^2 - 2xt_j t + xt_j^{\,2}\right) t^{2-k} t_j^{\,k-1} / 4kx \\ -\dfrac{\sqrt{\pi/2}\,\exp(xt_j^{\,2}/2)}{8x^{k-1/2}} t_j^{\,(2-k)^2} \cdot Erfi\left(\sqrt{x/2}\,(2t - t_j)\right) \end{array} \right)$$



$$x = -2\pi / \tau_m^2$$

$$B^{(k)}(u) = \begin{cases} 0 & when \;\; D > 0 \\ 1 & when \;\; D < 0 \end{cases}$$

CDD: correct decision duration

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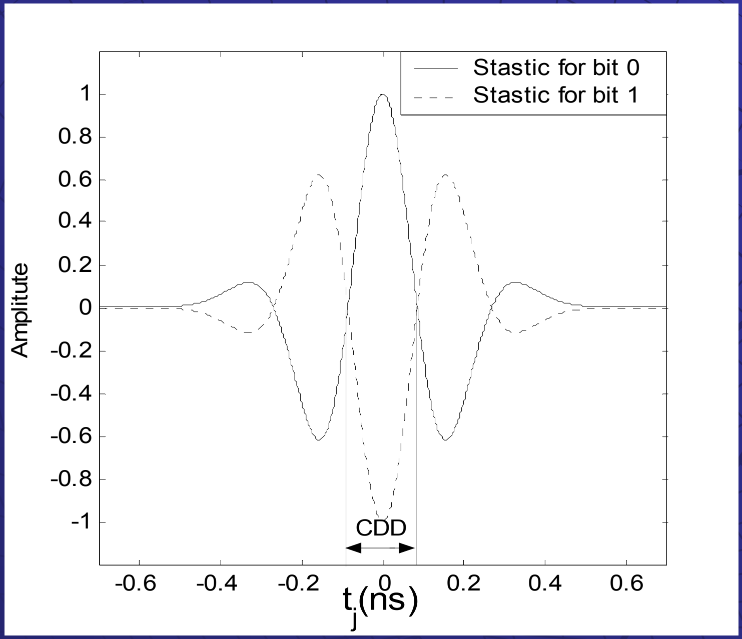
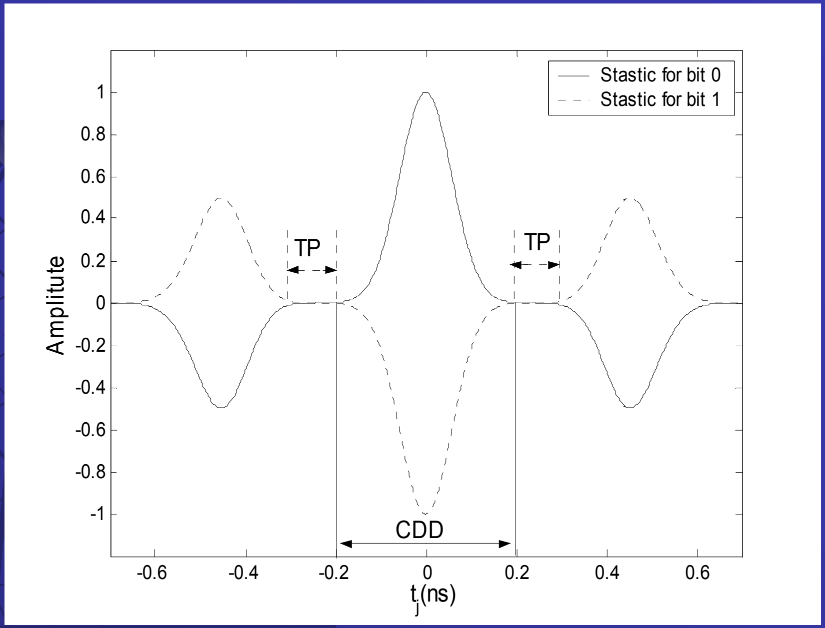
Performance of Proposed Scheme

Gaussian and High-order waveform



Gaussian Approach



Proposed Approach

--Proposed scheme provides longer CDD **with same** τ_m

--In addition, it provides the transition period (TP)

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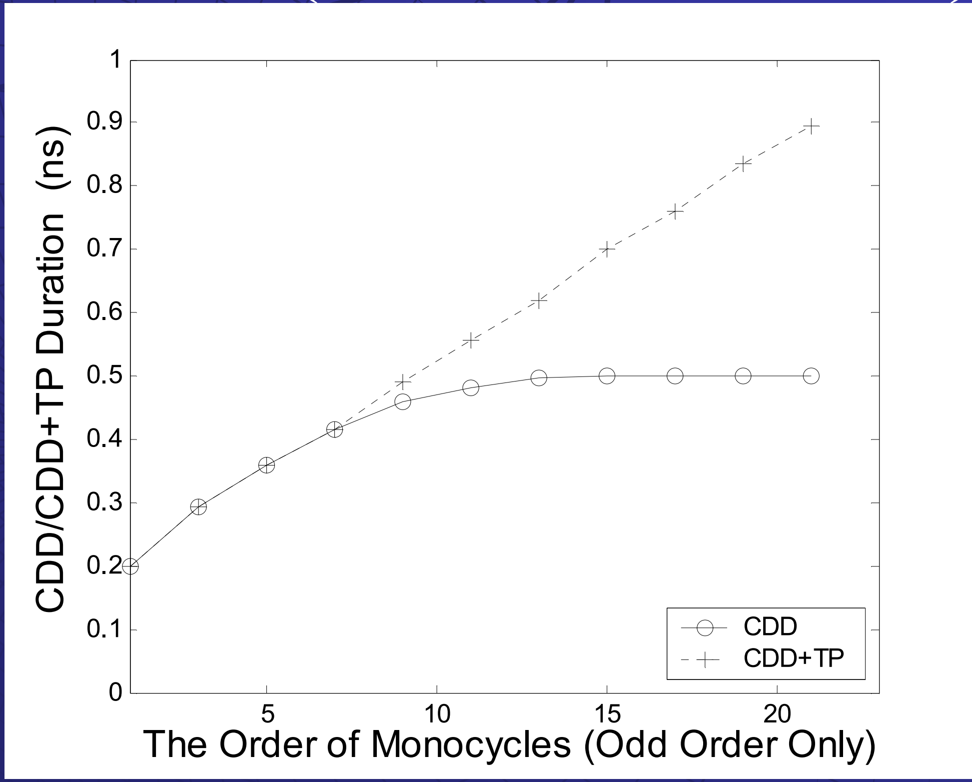
Why Select Order 15?

- When N<7, the value of CDD and CCD+TP are identical

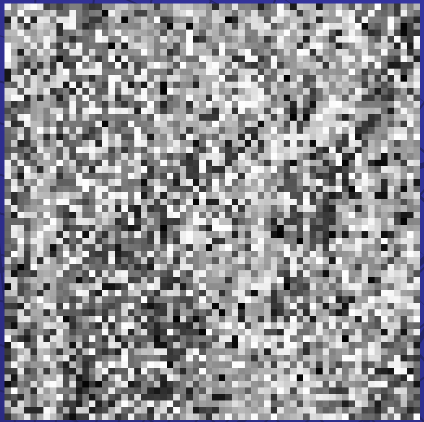
$$H(t) = A_H \left(t^{\mathbb{N}} \cdot \exp[-2\pi(\frac{t}{\tau_m})^2] \right)$$



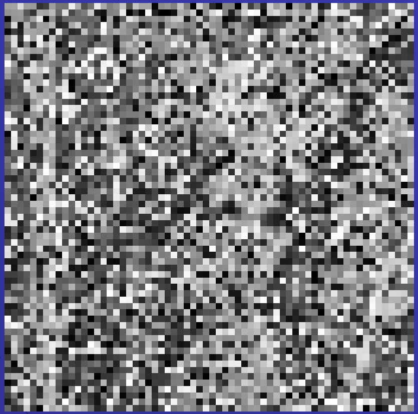
Simulation Results

Max Time-jittering=*0.20ns*

Conventional Gaussian-PPM approach



100 Multi-Users



200 Multi-Users

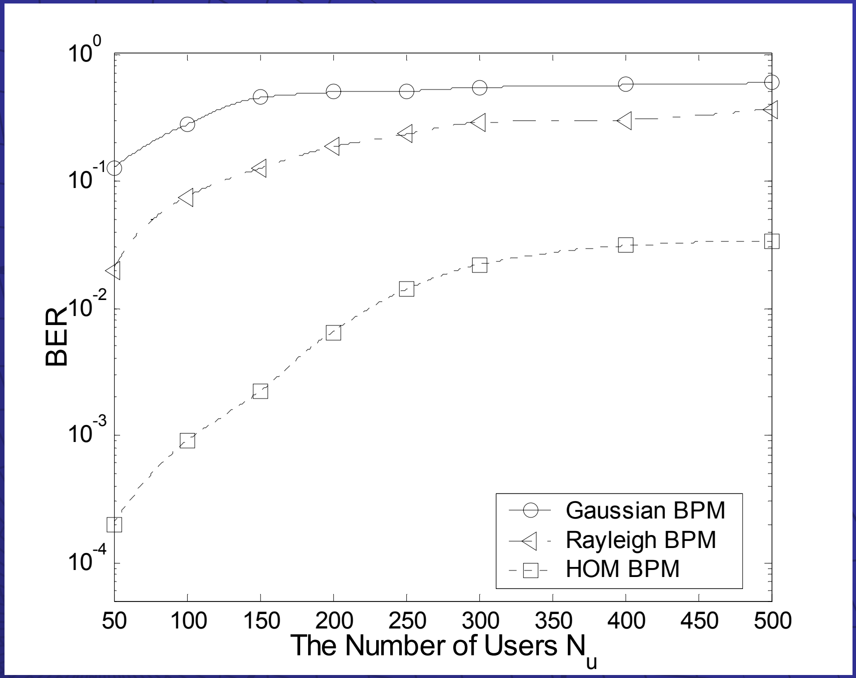
Our HOM-BPM approach

100 Multi-Users

200 Multi-Users

Simulation Results (II)

The effects of multiple-access when there is timing jitter



Ns=100 and maximum timing jitter $T_{Max,j}$=0.2ns

t_f: 100ns, T_c: 1.5ns, T_m: 0.7ns, S/N: 20dB

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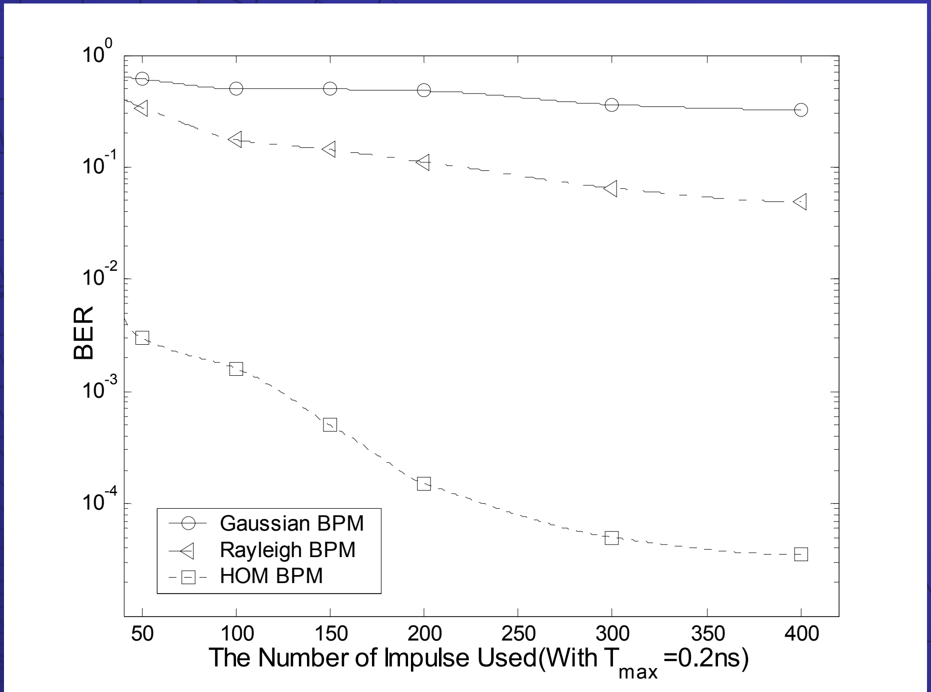
Simulation Results (III)

The impact of Ns when considerable timing jitter is present



$T_{Max,j}$=0.2ns

The proposed design can achieve reasonable BER even Ns=50. good for bandwidth efficiency.

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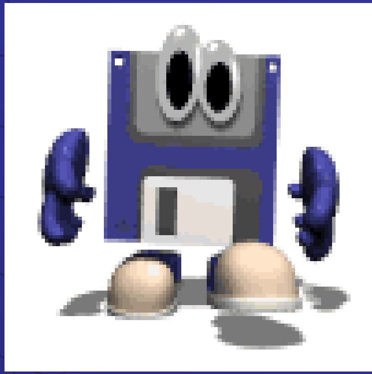
Conclusion

- We propose a waveform modulation scheme for timing jitter-robust UWB communication
- The wave form can be generated by the linear combinations of a set of derivatives.
- It can achieve better bandwidth efficiency

Content

Bi-phase UWB Modulation

Cross-layer QoS Content Deliver



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Motivation

- Significant difficulties in developing IP-based wireless data networks to meet QoS requirements

-- Dynamic Link Characteristics

-- Resource Contention

- The conventional protocol structure is inflexible as various protocol layers can only communicate in a strict manner.

Motivation

- In such a case, the layers are designed to operate under the worst conditions, rather than adapting to changing channel conditions.

➔ This leads to the inefficient use of spectrum and energy.

- Adaptation represents the ability of network protocols and applications to observe and respond to the channel variation.

➔Central to adaptation is the concept of cross layer design.

Most Current Designs

- Proposed dynamic resource allocation schemes:

-- Power control, rate adaptation

-- dynamic channel allocation

-- beamforming

-- multiuser detection

-- joint design between power and beamforming, between rate adaptation and power control

- In general, the cross layer design involves the different layers in an overall protocol stack.

- The adaptation can also take place in the underlying layers such as the TCP and UDP, so that the application originally developed for different networks remain unchanged.

Technical Challenges & Solutions

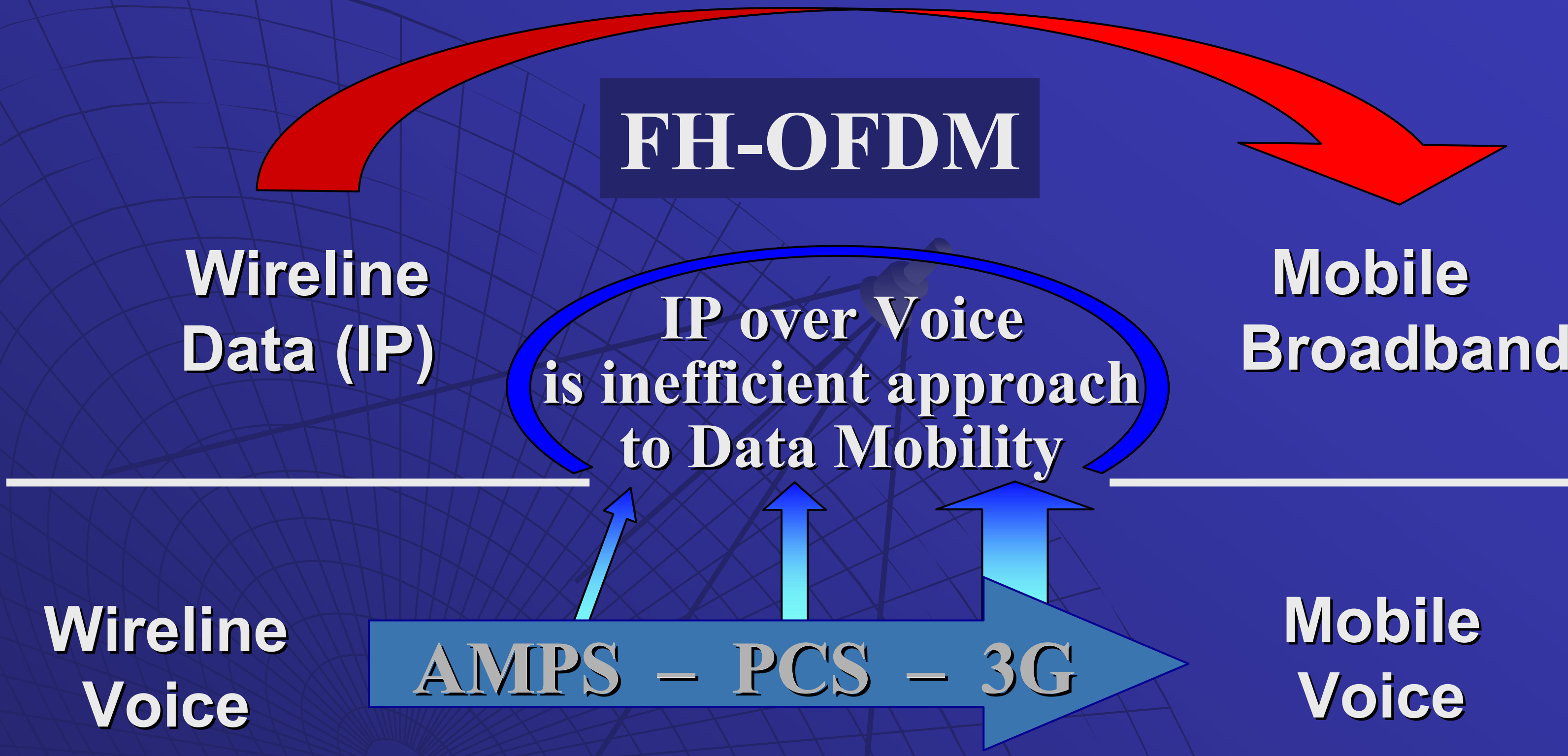
1. Application-layer: Adjust media source rate

2. Transport-layer: The protocol should differentiate various packet loss patterns, i.e. packet losses due to a network congestion or from channel errors

3. Link- and Network-layer: The link layer scheduler should allocate radio resources to various packet flows based on their QoS priorities.

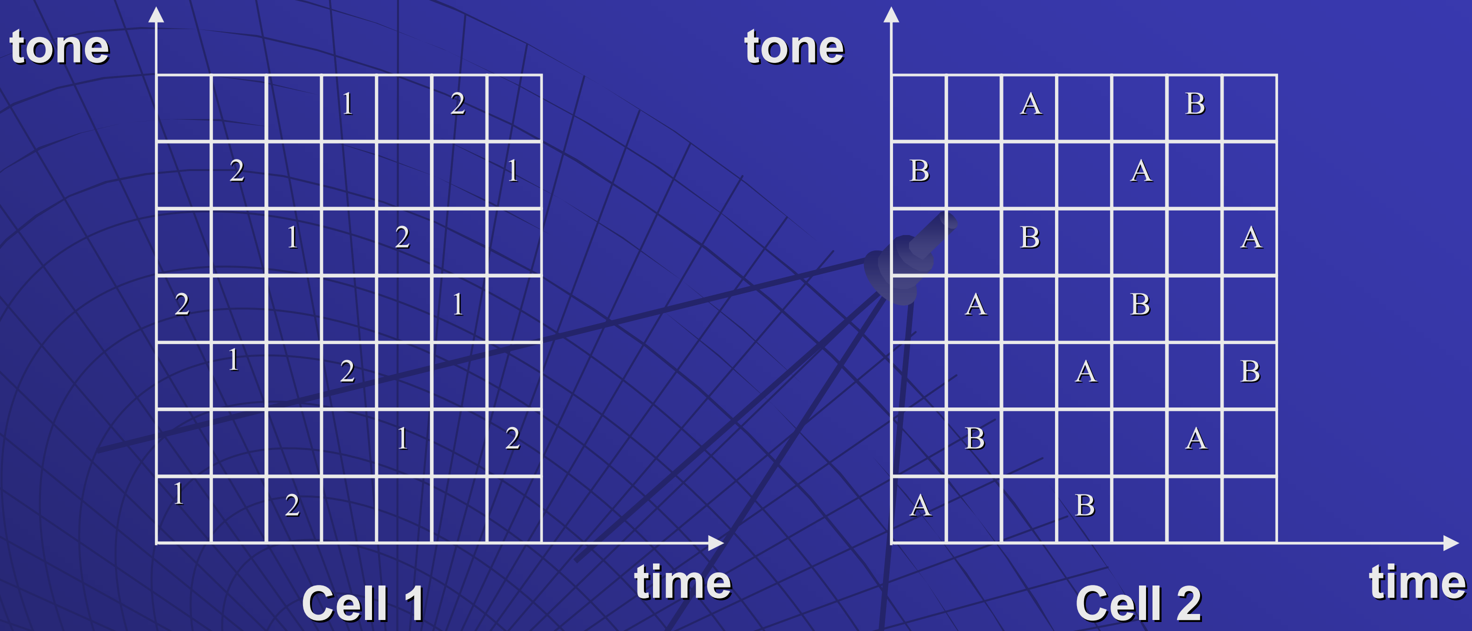
4. Predict Future Network and Channel Conditions.

All IP Network



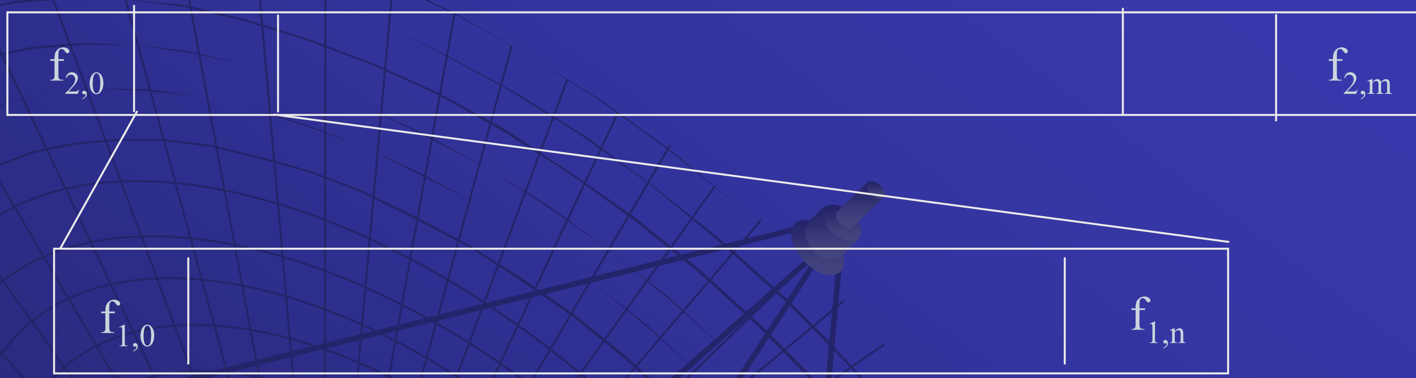
**FH-OFDM is to Broadband Mobile IP
What CDMA is to Cellular Voice**

FH-OFDM Illustrated



- No interference within the cell
- Interference averaged across cells *leads to*
  - Improved physical layer spectral efficiency (> W-CDMA)
  - More efficient support of bursty traffic

RNS FH-OFDM Illustrated



$$f^i = \sum_{s=1}^{2} f_s^i + f_q^i$$

FH pattern's design must:

i) avoid ambiguity when identifying users;

ii) reduce the chances of a collision between two FH patterns;

iii) distribute sub-carriers evenly; and

iv) keep adjacent FH patterns far from each other.

RNS OFDM Scheme (Cell Site 1)

User 1 (15⇔3,2) m=12, n=13	User 2 (21⇔9,8) m=12, n=13		Accumulator m=12, n=13
$f_{2,1} \times F_1 + f_{1,12}$			10, 10
$f_{2,2} \times F_1 + f_{1,0}$			11, 11
$f_{2,3} \times F_1 + f_{1,1}$	$f_{2,9} \times F_1 + f_{1,7}$		0, 12
$f_{2,4} \times F_1 + f_{1,2}$	$f_{2,10} \times F_1 + f_{1,8}$		1, 0
$f_{2,5} \times F_1 + f_{1,3}$	$f_{2,11} \times F_1 + f_{1,9}$		2, 1

RNS OFDM Scheme (Cell Site 2)

User 1 (17⇔8,7) m=9, n=10	User 2 (34⇔7,4) m=9, n=10		Accumulator m=9, n=10
$f_{2,0}\times F_1 + f_{1,8}$			1, 1
$f_{2,1}\times F_1 + f_{1,9}$			2, 2
$f_{2,2}\times F_1 + f_{1,0}$			3, 3
$f_{2,3}\times F_1 + f_{1,1}$	$f_{2,2}\times F_1 + f_{1,8}$		4, 4
$f_{2,4}\times F_1 + f_{1,2}$	$f_{2,3}\times F_1 + f_{1,9}$		5, 5

Transition among Different QoS States

Channel	High-QoS	Media-QoS	Low-QoS
DL and UL traffic	Yes	No	No
DL SNR report	Yes	No	No
DL and UL assignments & power control	Yes	No	No
Acknowledgment for DL & UL traffic channel	Yes	No	No
Sync channel	Yes	Yes	No
Timing control	Yes	Yes	No
Traffic channel request	No	Yes	No
Traffic channel grant	No	Yes	No
Fast paging	No	No	Yes
Slow paging	No	No	Yes
Access request	No	No	Yes
Access confirmation	No	No	Yes

Assignment of MAC States

- Service Priority/Pricing (QoS_{class}): Gold, Silver, …
- Traffic Class (QoS_{stream})

Stream QoS-ID QoS_{stream}	Description	BER	Segment loss	Segment order	Delay
15	E-911 session	4	4	4	4
14	Layer2 control	4	4	4	4
13	Layer3 control	4	4	4	4
12	Circuit voice (G729)	3	3	4	4
11	VoIP (G711-coded)	3	4	3	4
10	Stream video (H263)	3	3	3	4
9	Interactive Data	3	4	4	3
8	Multicast, RTP	3	3	3	3
7	Internet control	4	4	4	4
6	Internet data	3	4	4	2
5	Network management (OA&M) traffic	2	2	3	3

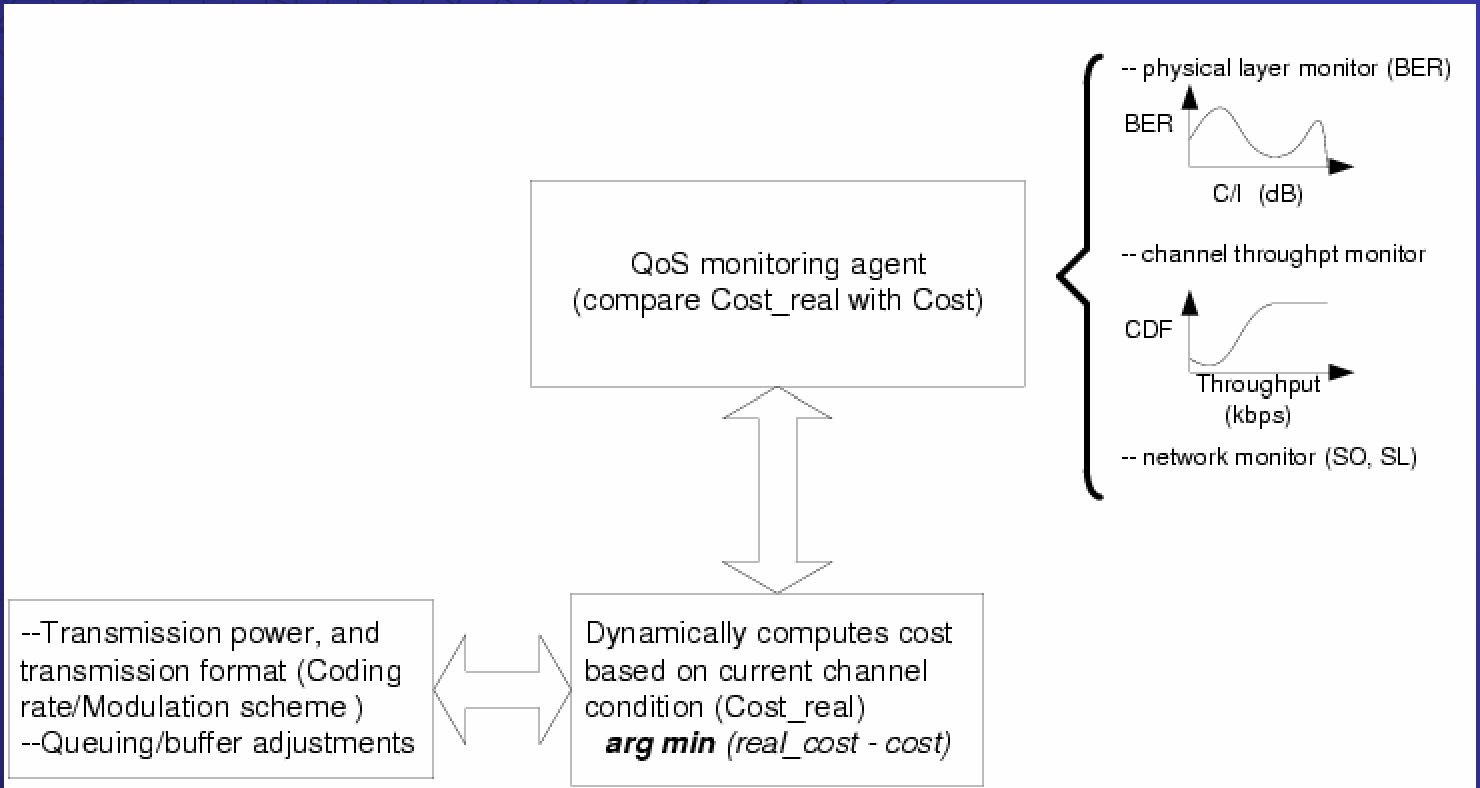
$$QoS = QoS_{class} * QoS_{stream}$$

MAC Scheduler

MAC scheduler determines physical resource based on cost measurement (applicable for both uplink and downlink traffic).

$$Cost = w_1 * BER + w_2 * SL + w_3 * SO + w_4 * DEL$$

$$\forall \; w_1 + w_2 + w_3 + w_4$$



Conclusion

•Proposed a cross-layer design scheme, especially among application, MAC and physical layer, for the wireless QoS content delivery.

•Our open end-to-end IP-based network structure allows inter-networking with heterogeneous networks and IP applications

Acknowledge:

Tiejun Lv
Haitao Zheng
Yingda Chen

For the details, please visit

http://binary.engin.brown.edu

Recent Journal Papers

- Jie Chen, Y. Chen, Tiejun Lv and W Zhu “A Timing-jitter Robust and FCC/WLAN Compliant UWB Modulation Scheme”, submitted to IEEE Wireless Communication
- Tiejun Lv, Hua Li and Jie Chen “Joint Blind Estimation of Symbol-timing and Carrier-frequency Offset of OFDM Systems over Fast Time-varying Multipath Channels”, to appear IEEE Trans. on Signal Processing
- Tiejun Lv, Jie Chen, and Hua Li “Low-complexity Blind Symbol Timing Offset Estimation in OFDM Systems”, to appear in EURASIP Applied Signal Processing, 2004
- Jie Chen, Tiejun Lv and Haitao Zeng “Joint Cross-layer Design for Wireless QoS Content Delivery”, to appear in EURASIP Applied Signal Processing, 2004
- Guolin Sun, Jie Chen, Wei Guo, and K. J. Ray Liu, “Signal Processing Techniques in Network-aided Positioning: A Survey”, to appear in IEEE Signal Processing Magazine, 2005