UWB Communications – Initial Results

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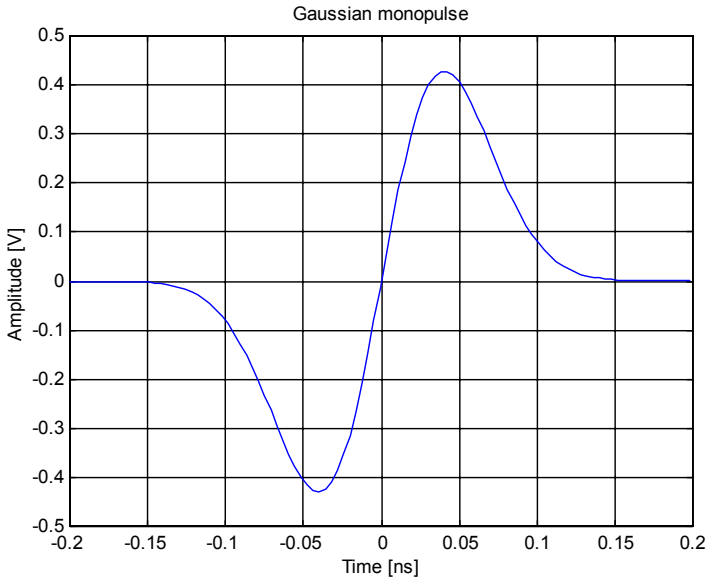
Outline

- UWB definition and signaling techniques
- FCC mask and application constraints
- Brief overview of existing technology
- Rate/range tradeoff
- Research goals:
  - high/flexible rate infostations and sensor networks
  - high speed home and business networking applications
- PHY & MAC:
  - design, modeling, simulation, & prototyping

UWB signal

- bandwidth > 25 % of center frequency
- or bandwidth > 1.5 GHz

- impulsive signaling (?)

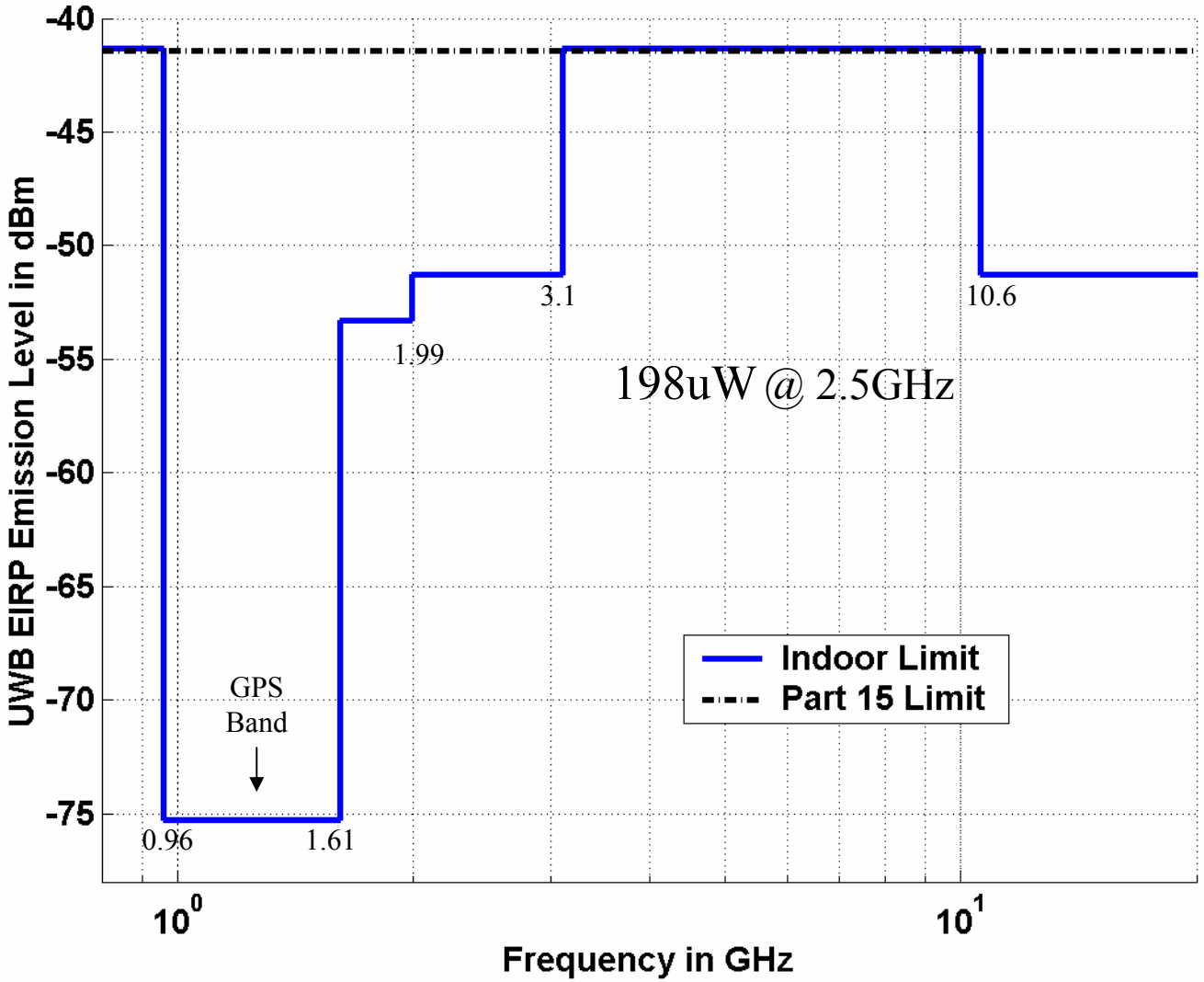


Gaussian monopulse

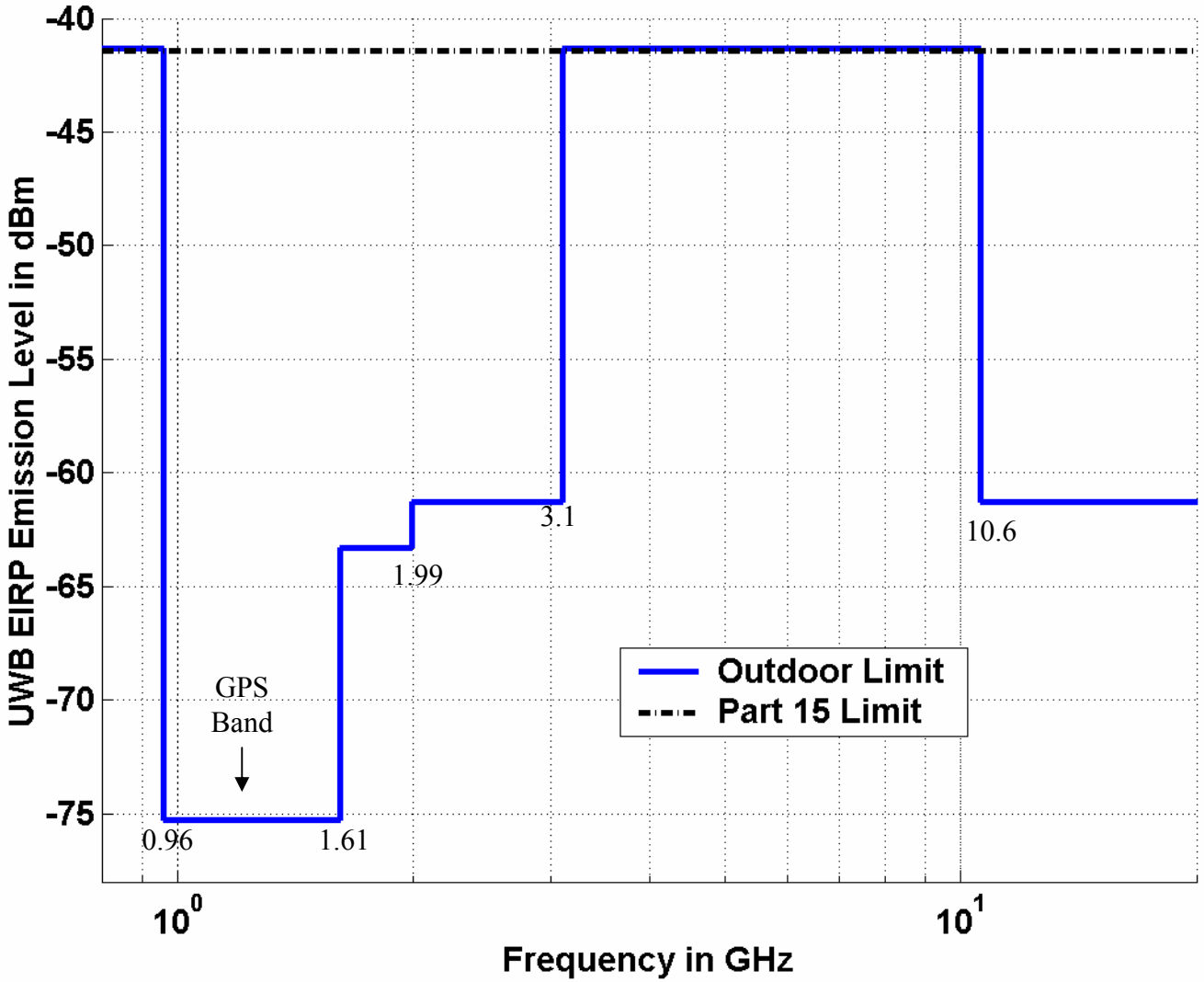
FCC UWB constraints

- Deep frequency notch in the GPS range: .96-1.61GHz
- Commercial communication systems can only operate in the range 3.1 – 10.6 GHz
  - Outdoor : only handheld devices and peer to peer operation
  - Indoor: no usage restrictions- targets high speed home and business networking devices

UWB Emission Limit for Indoor Systems



UWB Emission Limit for Outdoor Hand-held Systems



Challenges

- "Fitting within the mask":
  - antenna, signal, and transmitter front end design
- Communicating at high rates (500 Mbs?)
- Is "carrierless" communication still possible?
- Significant indoor multipath delay spread
- Self (multiple access) & other system (narrowband) interference.
- High degree of rate/range adaptivity

Existing technology

bandwidth [GHz]	carrier [GHz]	rate [Mbps]	Tx power [uW]	range [m]	walls
1-4 none fits	1-4.5 FCC mask	.1-50	50-400 FCC 198@2.5	10-15	2

signaling	PPM	wavelet DS-SS	doublet DS-SS

multiple-access	dithering PPM code	TDMA per cluster/ CDMA between clusters

no MAC or PHY standard

Home UWB channel characterization

(Ghassemzadeh etal.'01 AT&T Labs Research -23 houses)

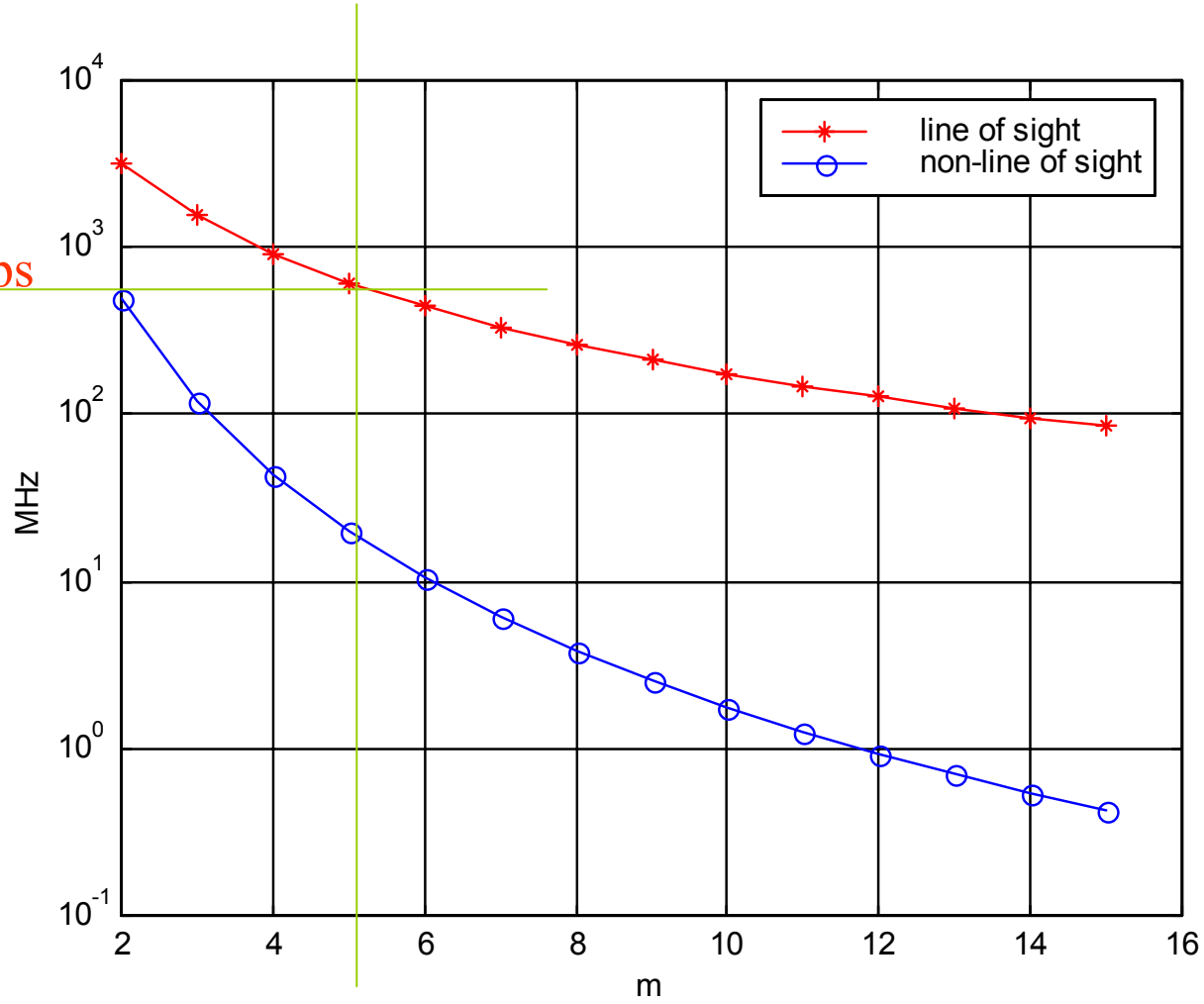
carrier frequency 5.25 GHz bandwidth 2.5 GHz

range 1- 15 m walls 1- 4

	path loss exponent	RMS delay [ns]	strongest path [%]	# of paths 70% power	coherence BW [MHz]
LOS	1.8	7	33	7	90
NLOS	3.5	10.2	7	40	29

maximum doppler frequency - 1 Hz and average - .1 Hz

Symbol rate vs distance



500 Mbps

5 meters

NF = 10 dB

Gt=Gr = 0 dB

Eb/N0 = 10 dB

binary

General research goals

- Channel and antenna characterization
- Signal and receiver design (Di)
- MAC protocol design (Mustafa)
- Simulation testbed design and analysis (Sridharan)
- Complexity/rate reduced designs (Jim)
- System prototyping/Front end design

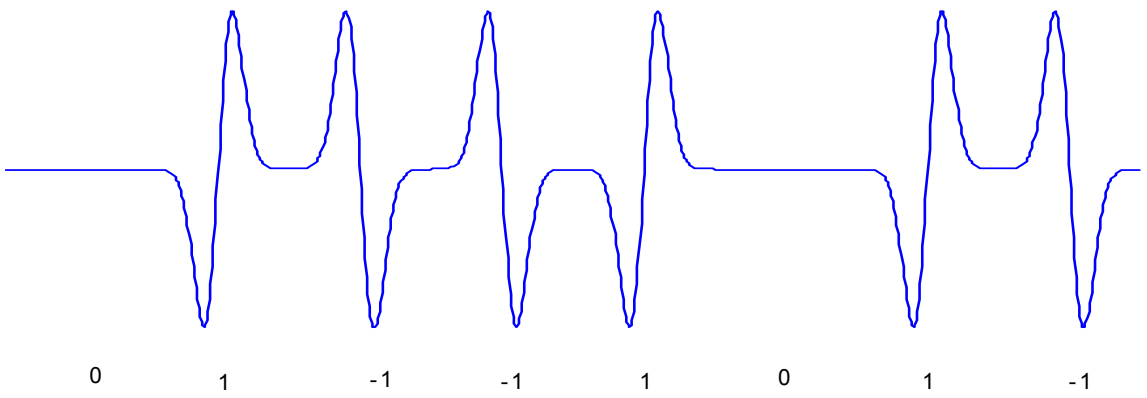
Signal design

- Robustness
  - Multipath/channel dispersion (self interference)
  - Multiple access interference
  - Narrowband interference
- Rapid acquisition
- Reduced complexity detection
- Flexible rate/multiple access adaptive design

Ternary sequence direct sequence spread spectrum (TS DS-SS) UWB

- Impulsive communications naturally allows for "turning off" the carrier.
- Use the "off" state as the zero coefficient for DS-SS.
- Perfect periodic autocorrelation for a number of lengths.
- TS DS-SS signals
  - significantly improved autocorrelation
  - improved cross-correlation (most likely)

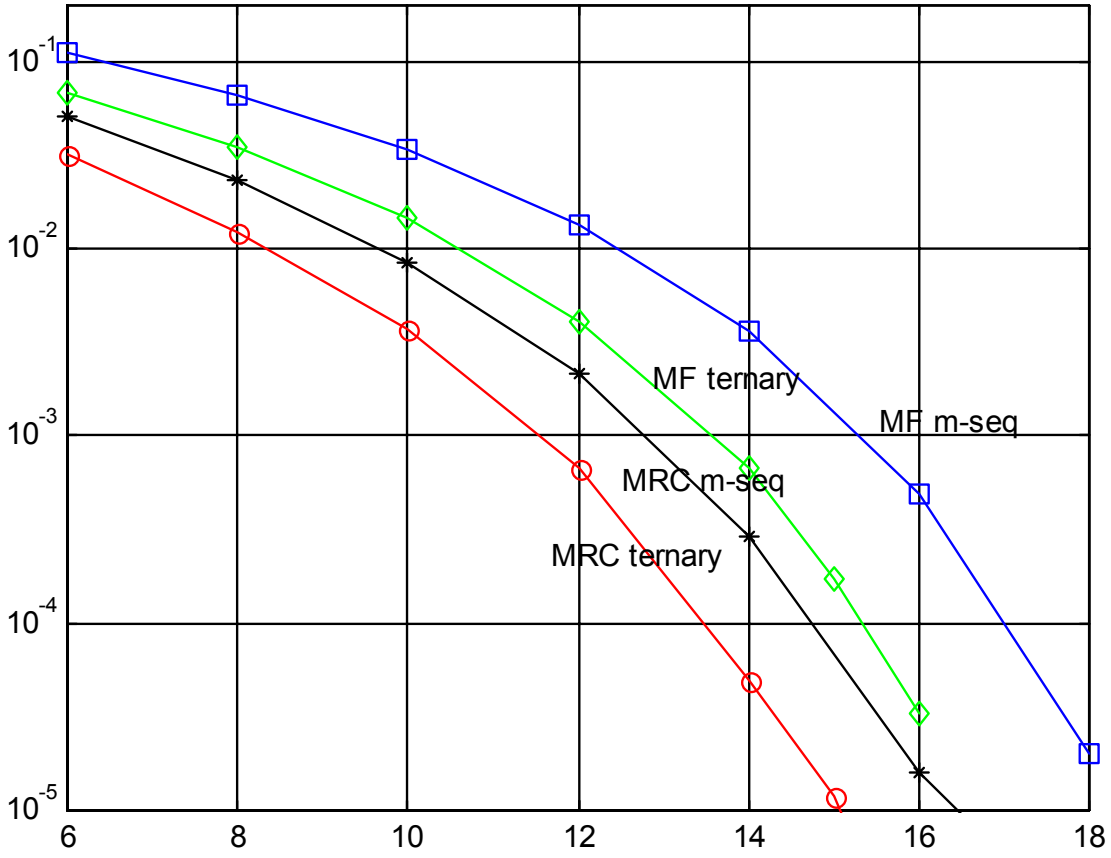
Gaussian monopulse ternary sequence



- sequence coefficients in {-1,0,+1}
- orthogonal PPM a special case: contiguous set of +1s & 0s
- smaller number of zeros, smaller peak to average ratio

Matched-Filter (MF) vs Maximal Ratio Combining (MRC)

M-sequence vs ternary sequence



BW = 2.5 GHz

R > 300Mbps

3 paths

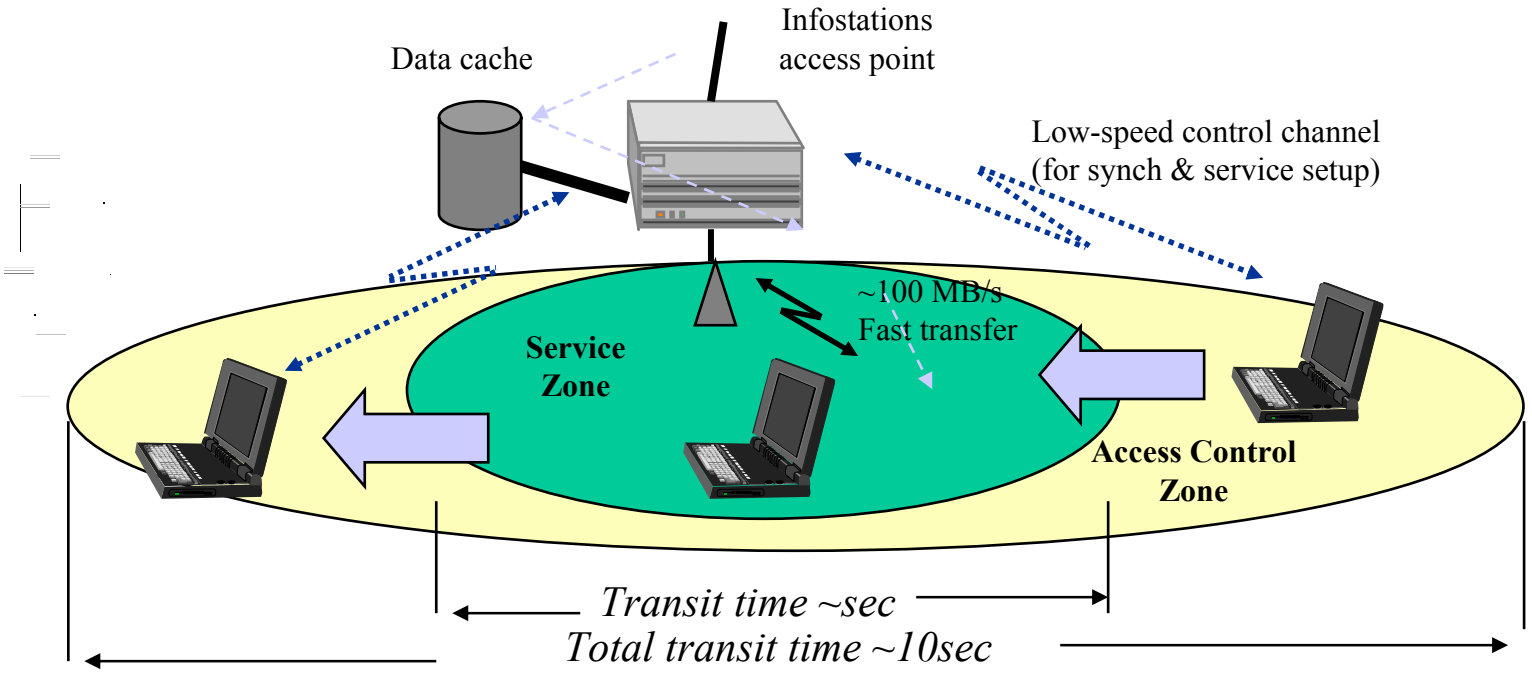
$$x = \{-1 \quad -1 \quad 0 \quad -1 \quad 0 \quad 0 \quad 1\}$$

MAC Protocol Design for UWB

- Suggest initial designs of burst-traffic oriented MAC protocols:
  - Infostation UWB
  - Sensor Network UWB

UWB Infostations: Service Model and Protocols

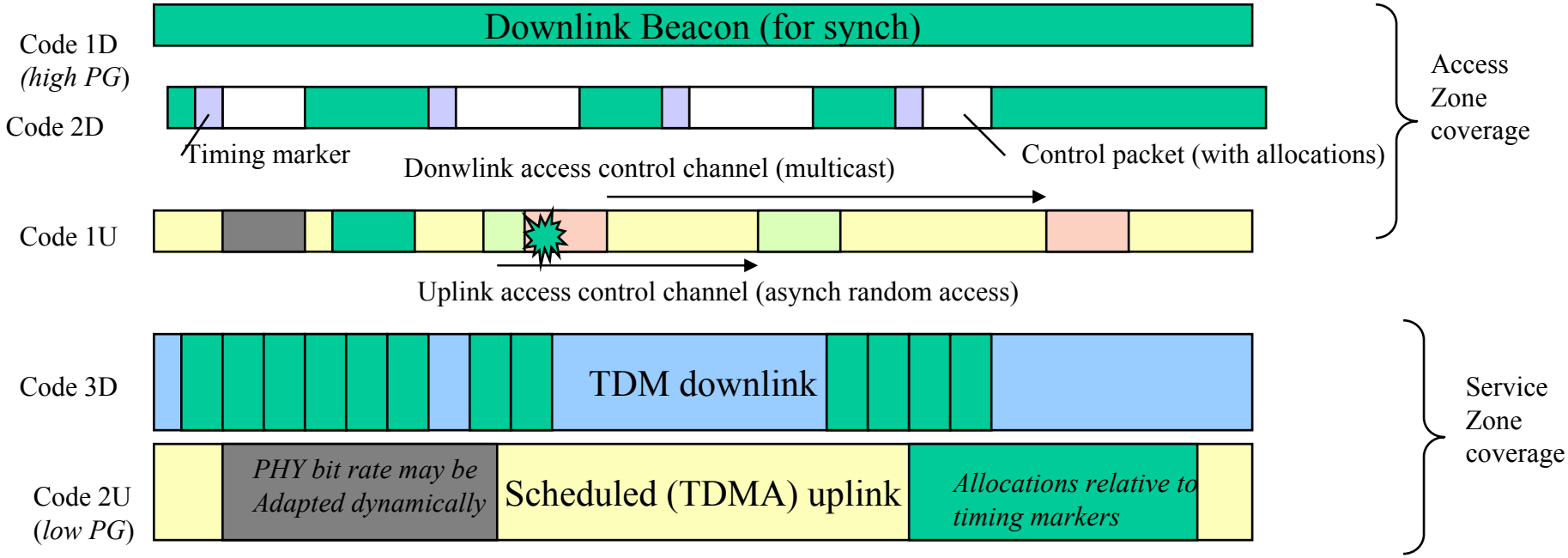
- Mobile user passes through Infostations in sec during which ~MB files are downloaded from (or uploaded to) network
  - Requires fast synchronization and service setup
  - Motivates 2-tier architecture with ~10m service zone (for high-speed data transfer) and ~50m access control zone (for sync, authentication, ..)



UWB Infostations: MAC protocol design

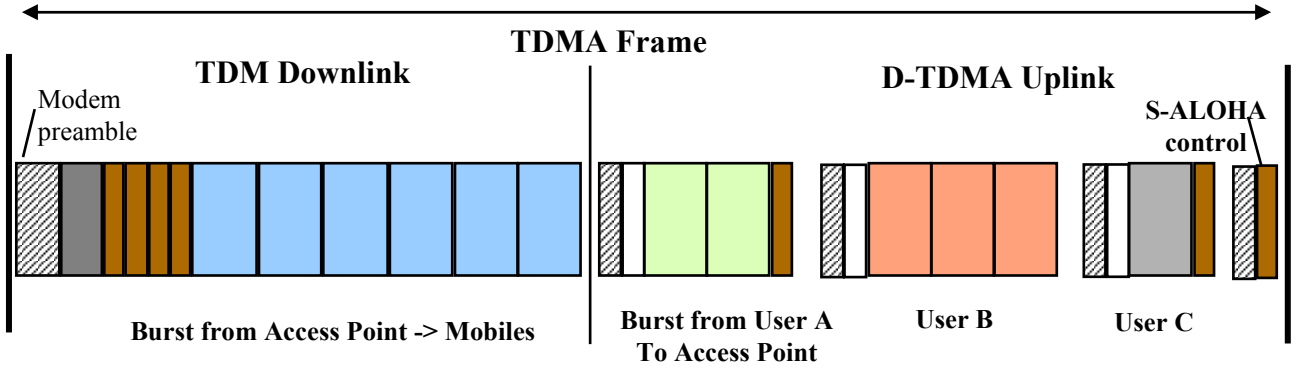
- MAC optimized for burst-mode file transfer rather than continuous TCP flow or stream/QoS services
  - Reduces MAC complexity relative to current proposals (e.g. Hiperlan2 or 802.16)
  - May simplify synch and reliability requirements for UWB PHY

Specific MAC example based on UWB with DS/CDMA coding:



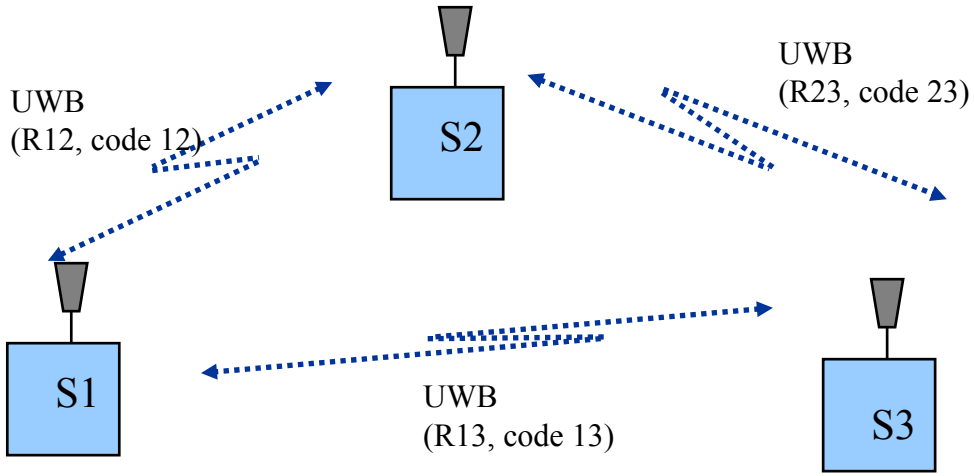
UWB Infostations: MAC protocol design (contd.)

- Other MAC schemes without the use of DS/CDMA also possible
  - For example, a dynamic TDMA/TDD scheme similar to WATM, Hiperlan2, 802.16 may be used
  - Requires TDMA framing with short random access control slots and longer data slots
  - Implies packet-by-packet synch on uplink (….min preamble overhead required for UWB?)



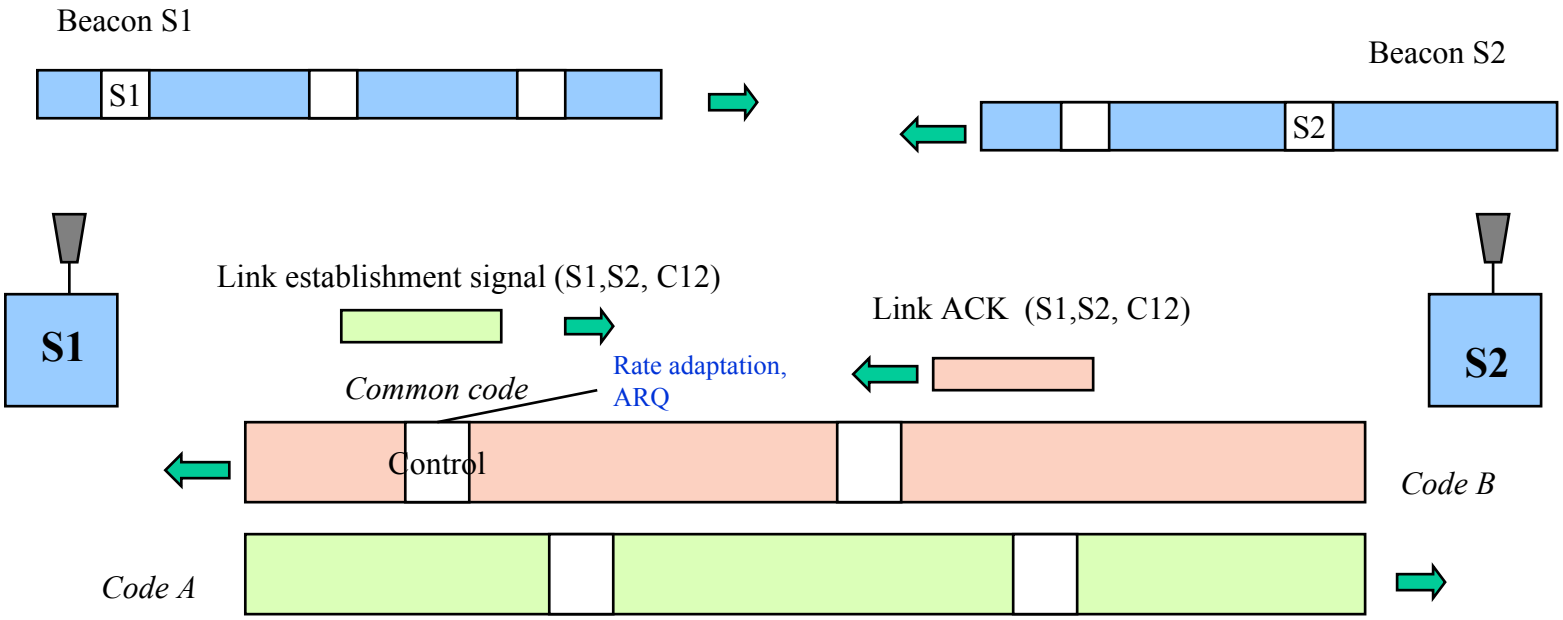
UWB Sensor Networks: Usage Scenario

- UWB potentially well-suited for sensor networks
  - Bit-rate readily traded off against range
  - Multiple radio links with single UWB RF (..simplifies MAC layer coordination among nodes)
  - Robust to interference from both UWB and non-UWB interferers
  - Low cost silicon for integrated sensor device



UWB Sensor Networks: MAC/Link Layer

- Potential MAC/link layer based on DS/CDMA UWB PHY:
  - Continuous beacon for synchronization & sensor ID broadcast
  - Low bit-rate, high-spreading gain common link establishment channel with a single code used in random access mode
  - Handshake protocol for setting achievable link bit-rate with dedicated code



SAW Filter RAKE