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Title	OVERVIEW OF STC+OFDM PHYSICAL LAYER PROPOSAL FOR IEEE 802.16.3
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Re:	Call for Initial Proposals for 802.16.3 BWA PHY Layer (2000-9-15) see 802.16.3c-00/43
Abstract	A brief summary of a physical layer proposal based on space-time coded OFDM with QPSK subcarrier modulation.
Purpose	Discussion and development of 802.16.3 BWA PHY.
Notice	
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802.16.3 PHY Proposal Summary: Space-Time Coded OFDM for MMDS

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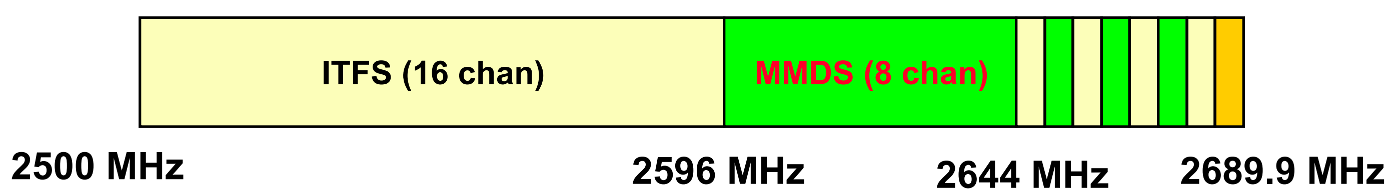
MMDS Channelization

- 2596 MHz - 2686 MHz is allocated for MMDS application in the U.S.
- 2644 MHz - 2686 MHz are interlaced with ITFS
- 2686 MHz -2689.9 MHz can be used as MMDS Response
- Each of the MMDS and ITFS channels are 6 MHz wide



MMDS Application Model

- Broadband Fixed Wireless Services
  - Residential: 2-4 Mbps down, 256 - 384 kbps up
  - Small Business: 2-5 Mbps down, 256 - 1000 kbps up
  - Primarily IP Services, 99.9% availability, 10^{-6} BER
  - Bandwidth Efficiency > 2.5 bps/Hz/cell
- Two way communications accomplished by either
  - TDD in the MMDS band, or
  - A different band/service such as 3G for uplink
- Reasonable Subscriber Unit Cost and Size, self-installation desirable

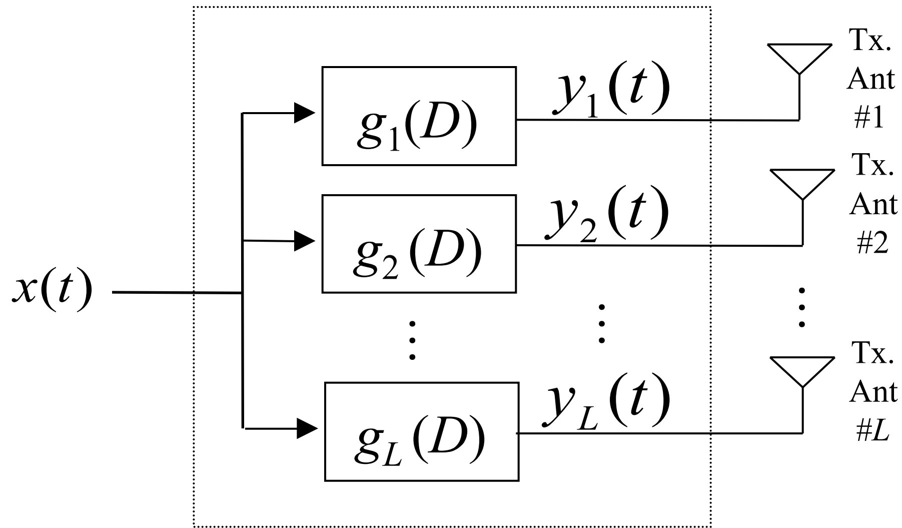
Shortcomings of Conventional Approaches and Remedies

- Super cell with line-of-sight (LOS) coverage provides only limited capacity, limited availability, and is potentially difficult to install
- Highly sectored solutions are impractical due to propagation environment and non-uniform subscriber distribution
- High-order modulation is sensitive to multipath and other impairments
- The remedies are
  - Aggressive use of spatial / frequency / time diversity
  - More robust modulation / coding and signal processing techniques in the presence of multipath interference to achieve non-LOS coverage with reasonable complexity

Characteristics of OFDM

- OFDM is a multi-carrier transmission scheme in which a high-rate data stream is transmitted over a number of lower-rate orthogonal subcarriers.
  - It been proposed and/or accepted for broadcasting digital audio and digital television, IEEE 802.11, HIPERLAN, etc.
  - Efficient FFT techniques are used to eliminate hundreds of separate oscillators that derive the separate subcarriers.
  - It is spectrally efficient over conventional FDM as it allows the spectra of individual channels to overlap.
- For data rates beyond 3G, OFDM avoids high complexity of single-carrier equalizer for multipath with delay spread extending over tens of symbols.
- OFDM transforms a highly frequency-selective multipath channel into a block-fading channel facilitating implementation of pilot-assisted synchronization.

Convolutional Codes As Full Diversity Space-Time Codes



Convolutional Encoder

"Natural" space-time code associated with rate 1/*L* convolutional code:
Multiplex L output coded bits in space (among antennas) rather than time.

Practical examples of our earlier work on general space-time "Stacking Construction."

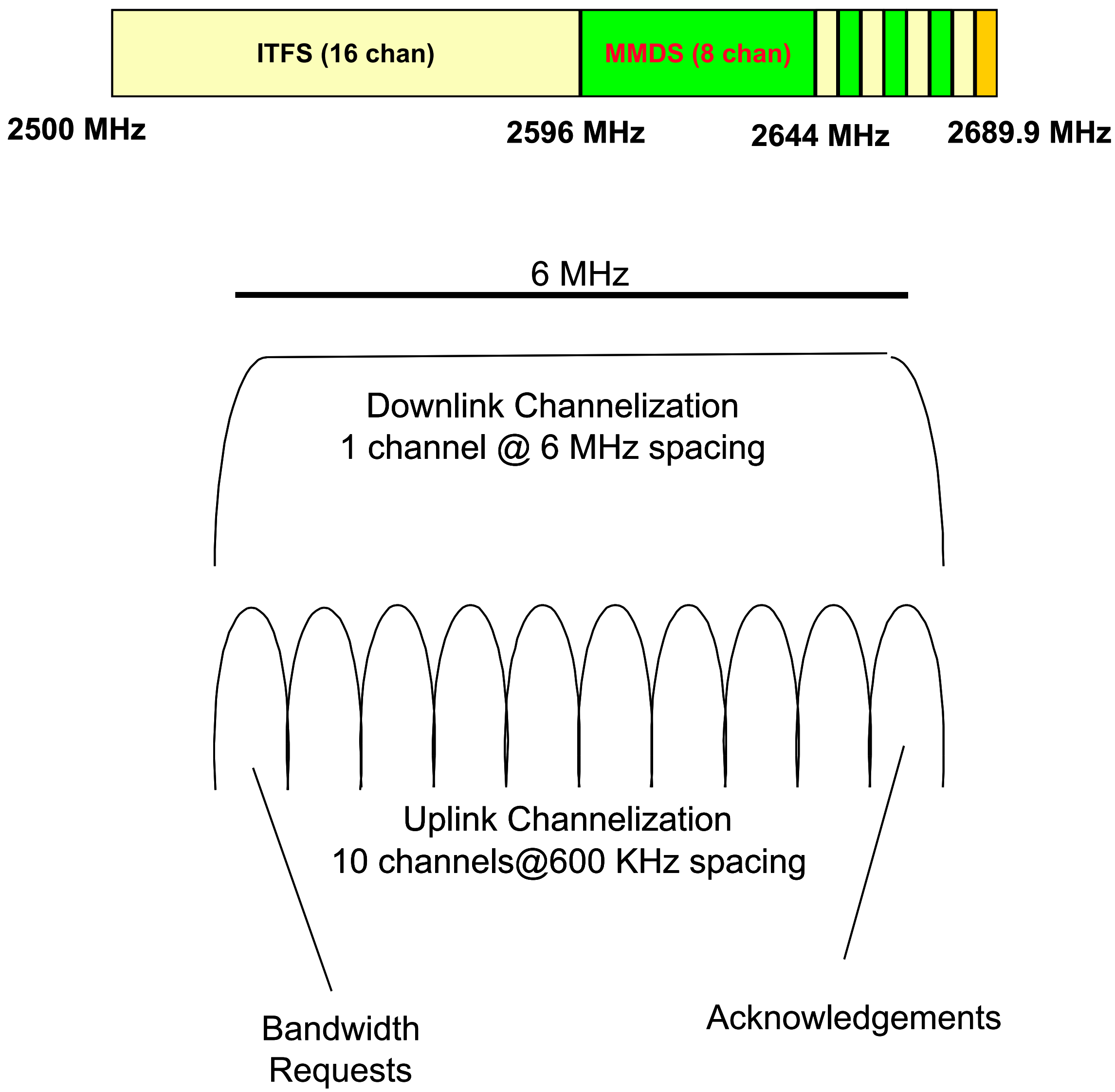
OFDM + “Space-Frequency” Codes Allows Favorable Design Trade-Offs

- OFDM front-end transforms ISI channel into a block fading channel.
- Space-Frequency codes can then be constructed to achieve any desired level of diversity using our MIMO block fading framework.
- Designer can trade diversity advantage for reduced decoder complexity by choice of code parameters.

QPSK, 2bits/sec/Hz, 1 Rx antenna

L	N	$d_{\max}$
2	1	2
2	2	3
2	3	4
3	1	3
3	2	4
3	3	5

A STC+OFDM System Design for MMDS Applications



- Each of the MMDS and ITFS channels are 6 MHz wide.
- Channel allocation suggests TDM duplex mode with proposed uplink/downlink channelization
- 2 transmit/2 receive antennas at user terminal
- 4 transmit/4 receive antennas at base station
- Conventional OFDM with QPSK subcarrier modulation.
- Rate 1/2 trellis-based space-time code (64-state)

Proposed STC+OFDM System Compares Favorably Against VOFDM

1-Ray	5 Mbps	10 Mbps	20 Mbps
STC+OFDM	3 dB	8 dB	13 dB
VOFDM	9 dB	15 dB	28 dB

2-Ray	5 Mbps	10 Mbps	20 Mbps
STC+OFDM	2 dB	8 dB	13 dB
VOFDM	6 dB	12 dB	24 dB

4-Ray	5 Mbps	10 Mbps	20 Mbps
STC+OFDM	1 dB	8 dB	12 dB
VOFDM	4 dB	10 dB	22 dB

- STC+OFDM allows transmission of 20 Mbps over 6 MHz channel in a Rayleigh fading channel at a C/I consistent with reuse
- STC+OFDM performance is not sensitive to channel model
- Gain over VOFDM is greater when fade is more severe

Proposed STC+OFDM System Yields Capacity Exceeding 2.75 bps/Hz/cell

	1x3 Reuse				2x2 Reuse with dual polarization			
	Sectors	D/L Freq	Cap/Sect	Cap/Cell	Sectors	D/L Freq	Cap/Sect	Cap/Cell
FDD	3	3	3.33	3.33	4	2	3.33	6.67
TDD w/ 75% time for D/L	3	3	2.75	2.75	4	2	2.50	5.00

- Per-cell capacity depends on Uplink / Downlink multiplexing / allocation, and the sectorization / reuse plan
- Conventional 1x3 reuse pattern is supportable with practical subscriber unit antennas.
- Tighter reuse using dual polarization and 4-sector cells requires only two 6 MHz frequencies

Adaptive Transmission Would Allow for Even Higher Throughput

Modulation	*Coding Rate*	*Throughput (bits/sec/Hz)*
QPSK	**1/2**	**4**
QPSK	1	8
16-QAM	1/2	8
16-QAM	1	16
64-QAM	1/2	12
64-QAM	1	24

- Space-time coded OFDM allows rate adaptation in space and frequency.

Conclusion

- STC + OFDM is the only solution to high data rate MMDS
  - Rayleigh fading channel
  - Slow fading (2 Hz doppler spread)
  - Delay spread between 0 and 5 μsec
- STC + OFDM allows for simple, robust, scalable transceiver design
  - No equalization is necessary
  - QPSK delivers high data rate
  - 64-state channel decoder