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# Benefits of OFDM for Mobile Broadband Wireless Access

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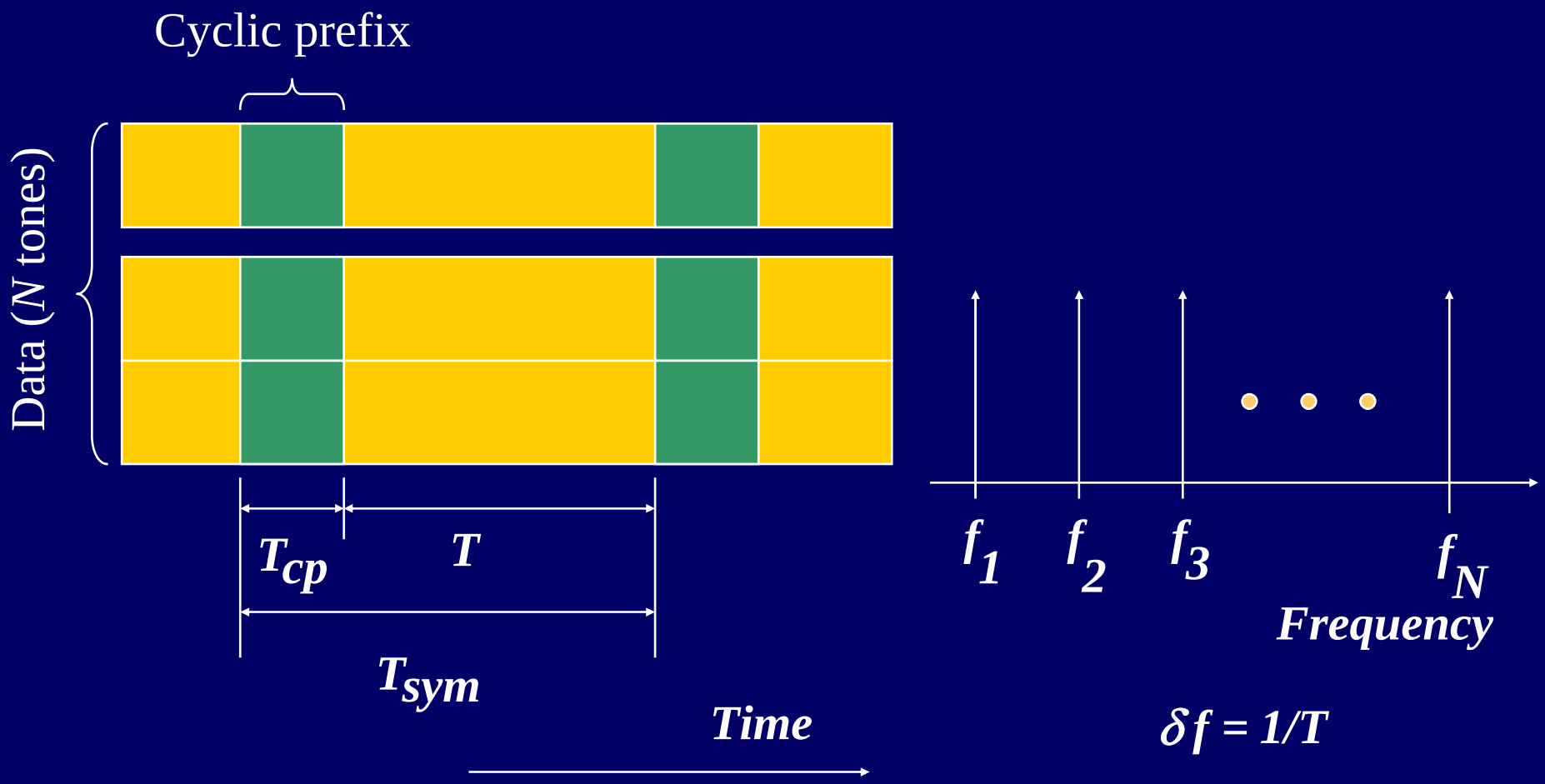
# Key OFDM Air Interface Design Advantages

- PHY/MAC
  - Intra-cell interference
  - Fine air-link resource granularity
  - Pilots
  - Power & Timing Control
  - Data Requests & Assignments
  - Fast Acks
- Other
  - Universal frequency re-use
  - True packet-switched air interface
  - Handoff support

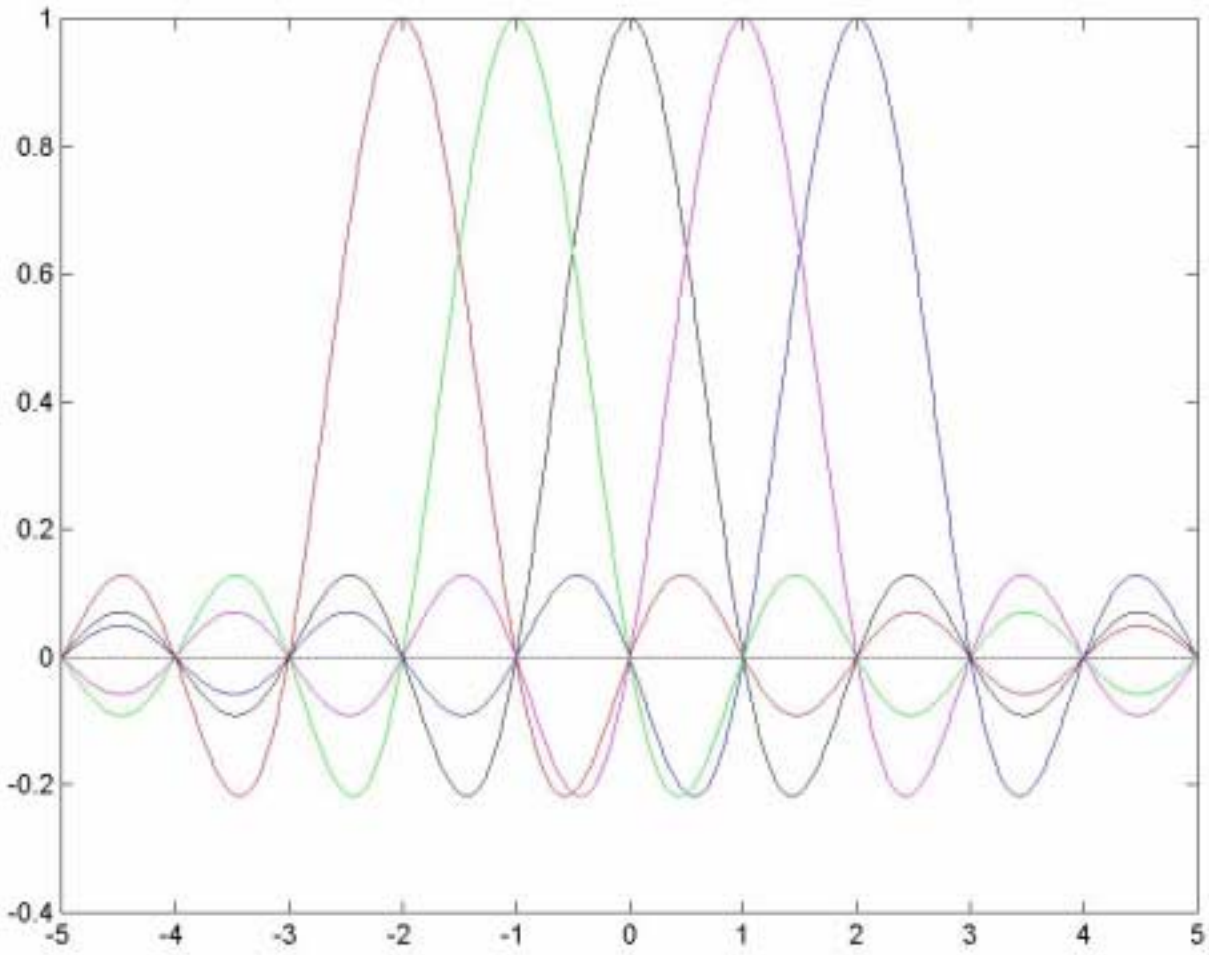
# Intra-cell Orthogonality

- Repeat portion of each OFDM symbol in cyclic prefix (CP)
  - Gracefully handles large delay spreads; eliminates ISI
  - Aids in synchronization
- By choosing appropriate parameters, each tone can be made *orthogonal*, even after multipath delay spread
  - Sinusoid waveforms (tones) are the only functions that preserve orthogonality over multipath wireless channels
  - In contrast, DS-CDMA codes do not have this property, and are not orthogonal under multi-path
- Significantly simpler receiver design for high data rates
  - No training overhead for RAKE or receiver equalizer

# OFDM Symbol Structure

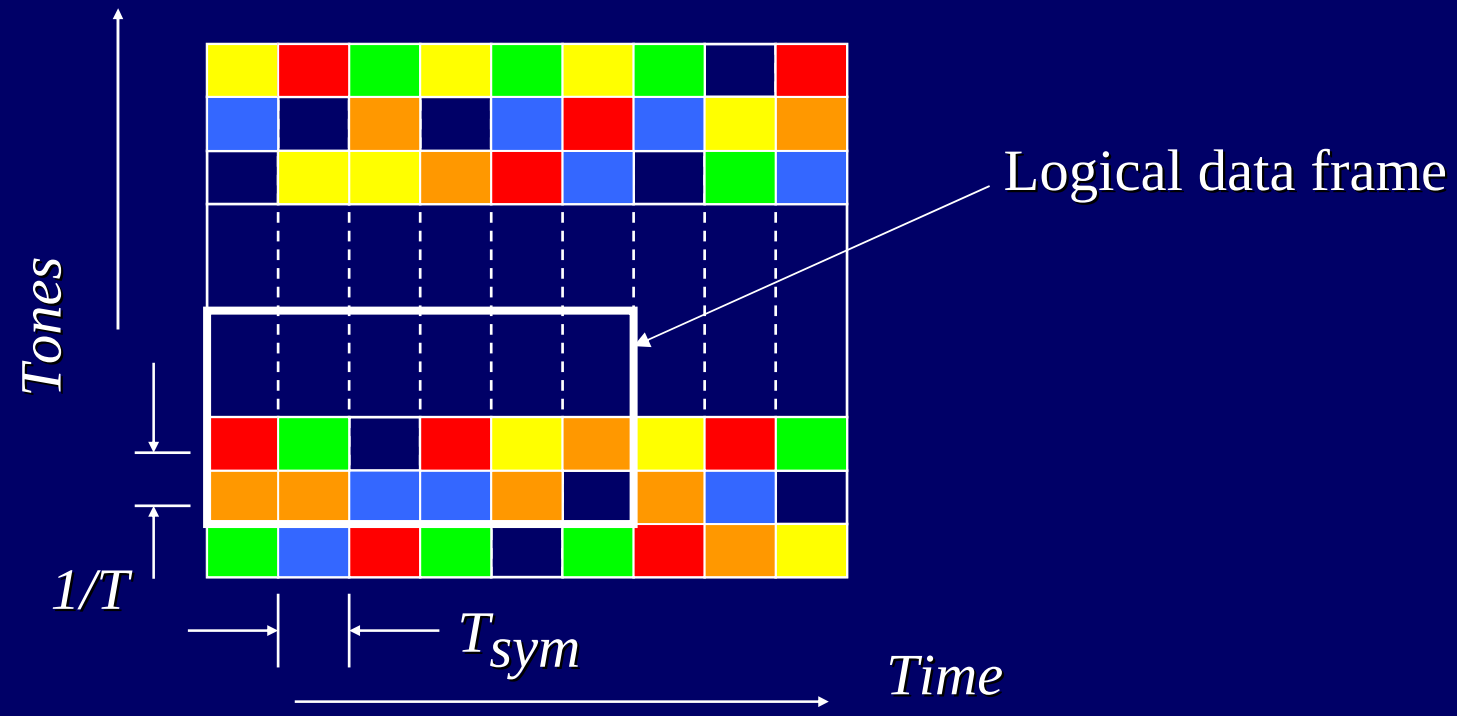


# Tone Orthogonality



# Fine Granularity of DL/UL Air-interface resources

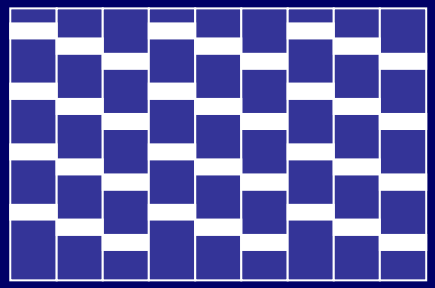
- OFDM supports fine granularity in distribution of air-link resources (time-slots, frequency tones)



# Fine Granularity Contd.

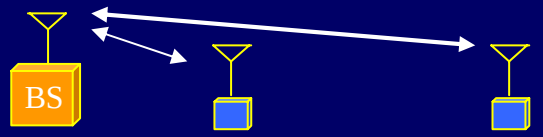
- Key attribute for multiple access
  - Smallest transmit/receive unit can be 1 bit
  - Allows for dedicated, low–overhead control channels, e.g., power control, timing control, uplink requests, etc.
  - Maximizes number of active users supportable
- Can avoid inefficient control channels based on messaging with addressing overhead
- Low cost of “starting and stopping” transmission of data traffic and control messages
- Facilitates multiple MAC states to optimize resource allocation and usage per user

# Pilots



- OFDM allows for time-frequency spaced grid of Downlink and/or Uplink pilots
  - Allows sharing of DL pilot tones across all users for efficiency and eliminates overhead for data and control frames
  - Supports per-user pilots on UL for coherent demodulation
  - Pilot tones can appear temporally “continuous” (e.g., mobiles see pilots every symbol time) to accommodate high-Doppler environments
  - Can be used to identify different Base Stations

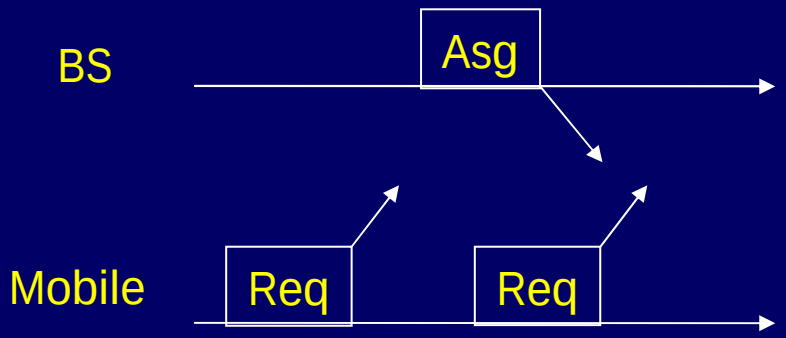
# Power and Timing Control



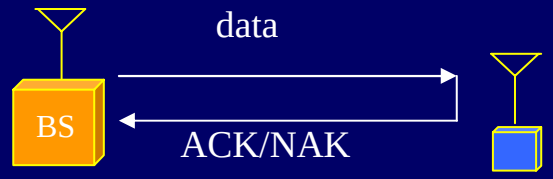

- Power Control
  - Intra-cell orthogonality in OFDM allows for Mobiles to transmit access requests without time-consuming and interference-generating transmit power ramp-up
  - Supports open- and closed-loop power control techniques for DL and UL
- Timing Control
  - Uplink transmissions synchronized to allow for single FFT in Base Station receiver
    - Slow update rate required even at vehicular speeds
  - Mobiles not actively transmitting and receiving data need only be timing-controlled

# Data Requests and Assignments

- Packet-switched DL
  - Base Station can assign DL time/frequency resources with minimal delay
  - Supports large user population with “high maintainence” data connections
- Packet switched UL
  - Can eliminate contention-based UL data requests
  - Can support deterministic UL data request times



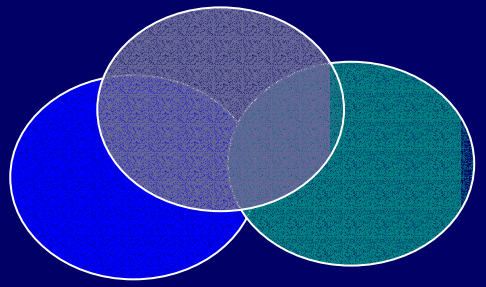
# Fast MAC frame ACKs




- Can support efficient ARQ ACKs/NAKs for MAC frames
  - Deterministic ARQ round trip time: Critical to maintaining QoS for highly interactive data services (e.g., Gaming, VoIP)
  - Minimize impact on TCP RTT timer evolution
  - Low overhead: Enabled by fine granularity

**Interactive Data**

# Universal Frequency Reuse

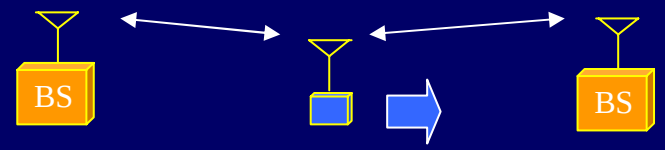


- OFDM allows for inter-cell interference averaging via frequency-hopping.
  - Allows for universal frequency reuse
  - Link budget can be designed for averaged (not bursty) interference
- Efficient use of expensive licensed cellular spectrum
- Supports smart antenna techniques for $< 1$ frequency reuse
- Enhances ease of deployment; reduces need for network engineering

# Packet Switched Air-interface

- Suitability for packet-switched UL and DL
  - Supports fully scheduled DL and UL
  - Allows resource partitioning on a MAC frame basis
  - Supports large number of Active and Dormant users
  - Very low overhead and latency for fast control channels (e.g., frequent MAC frame Acks, Data requests etc)
  - Mobiles not actively transmitting and receiving data only incur timing control overhead
  - UL Contention-based access distinct from data traffic
  - Rich QoS support for multiple traffic types with reduced signaling overhead

# Handoffs




- Allows for deterministic UL and DL latencies in handoff signaling
  - Crucial for vehicular speed handoffs
  - Contention-free UL data requests
  - No interference between random access and data traffic
  - Supports multiple simultaneous Mobile & BS air-links
- Supports QoS differentiation between random access from new mobiles versus handoff mobiles

**Better user experience**

# Summary

- OFDM based Modulation and Multiple-Access is ideally suited for packet-switched Mobile Broadband Air-interfaces
- Can elegantly achieve a complex balance amongst:
  - Simple transmitter & receiver design for broadband data rates with vehicular mobility
  - Lightweight, finely granular control structure
  - Supporting a large user population
  - High level of interactivity and low deterministic latencies
  - Embodying spread spectrum principles for interference control
  - Rich QoS feature set