Project	**IEEE 802 Executive Committee Study Group on Mobile Broadband Wireless Access** **<http://grouper.ieee.org/groups/802/mbwa>**
Title	**PHY and MAC considerations for an adaptive antenna-based MBWA air interface**
Date Submitted	**2003-03-10**
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Re:	This contribution is submitted in response to the Call for Contributions from the chair of 802.20 for its March 2003 meeting.
Abstract	This contribution goes over the characteristics of the MAC and PHY that drive various considerations on the joint design of the air interface especially for an adaptive antenna-based TDD MBWA air interface.
Purpose	To demonstrate the benefits of adaptive antennas in TDD MBWA systems and the importance of the coupled design of the PHY and the MAC towards an optimized solution that achieves the objectives of the 802.20 PAR.
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MAC and PHY considerations for an Adaptive Antenna-Based MBWA air interface

802.20 meeting #1
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Dallas, TX

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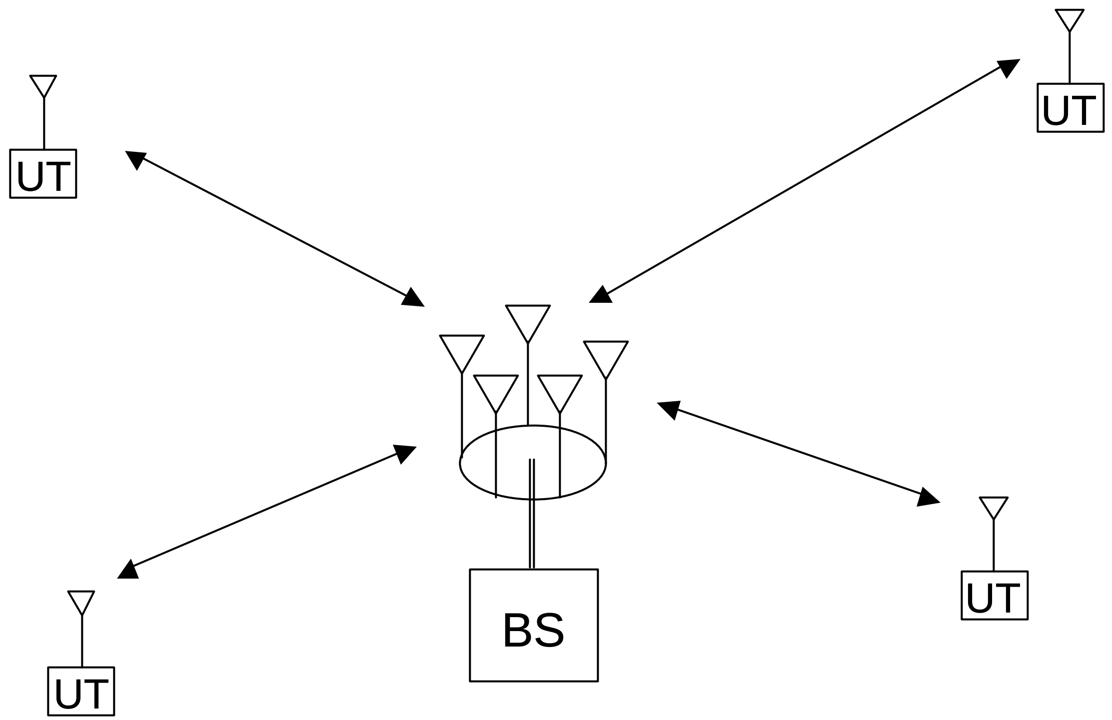
Outline

- **Summary of the benefits of Adaptive Antenna Arrays**
- **Application with multi-carrier TDD/TDMA air interface**
- **Design considerations for an efficient MAC for the proposed air interface**
- **General considerations for MAC and PHY designs**

Adaptive Antenna Arrays

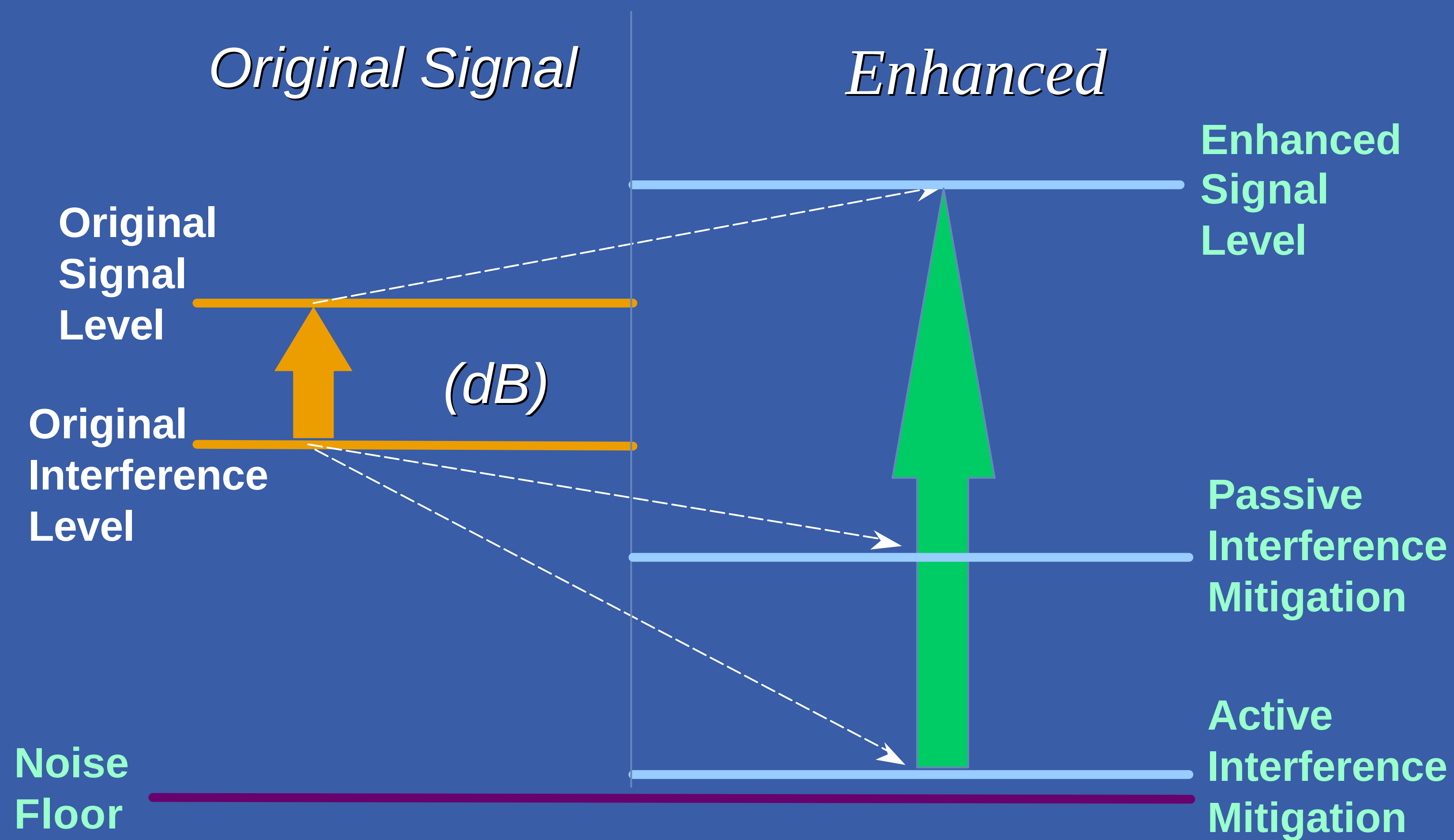


- Base Station (BS) has multiple antenna elements
- Multiple-antenna UT is not required
- Standard Antennas
- Adaptive Signal Processing

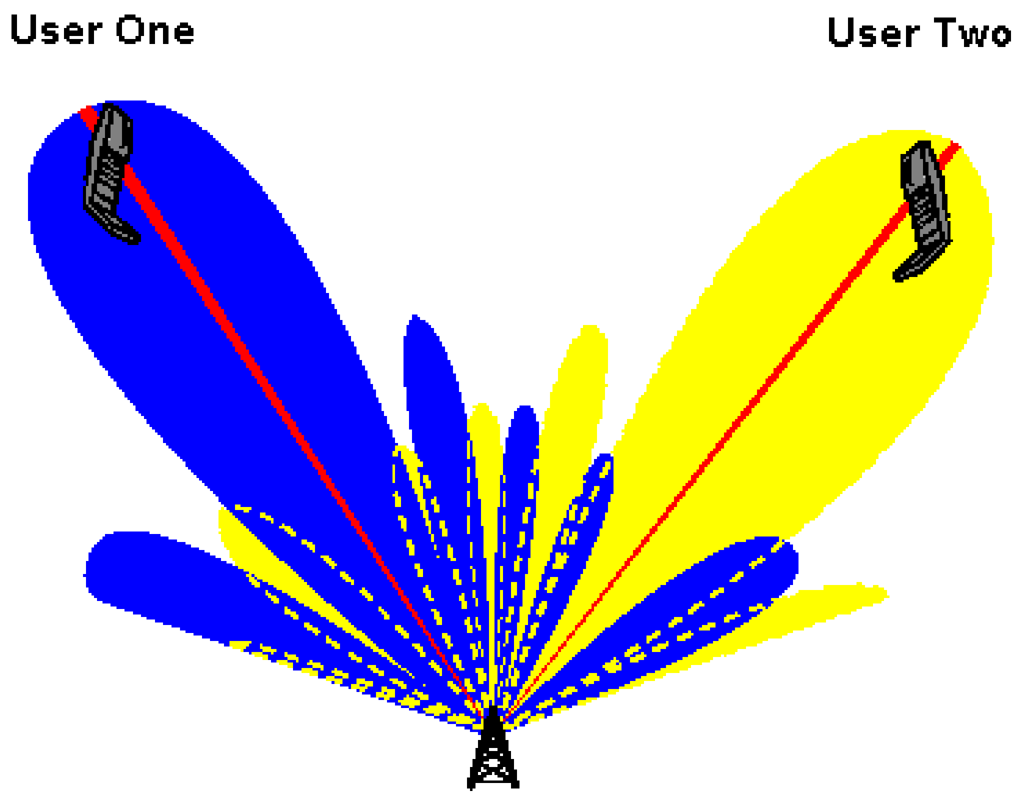
Adaptive Antenna Arrays: Summary of Available Benefits

Signal Gain	•**SNR improvement:** •Gain = 10*log(M), M=number of antennas •Total BS EIRP is unchanged from single antenna case •**Improves immunity to channel impairments** •Spatial diversity combats fast fading •Coherent combining mitigates multipath •**Improves link budget** •Reduced Tx power requirements •Increased cell size •Improved coverage
Interference Rejection	•**Reduced interference** •Improves intra-cell SINR •Reduces inter-cell interference •Reduces out-of-band interference •Permits network deployment without frequency planning
Spatial Multiplexing (SDMA)	•**Supports several co-channel users:** •Multiplies spectral efficiency •Aids collision resolution

Signal Quality Enhancement



Spatial Channels



Benefits extend beyond PHY

Adaptive Antenna properties such as "Spatial Collision resolution" offer the opportunity for new MAC designs with significant performance benefits.

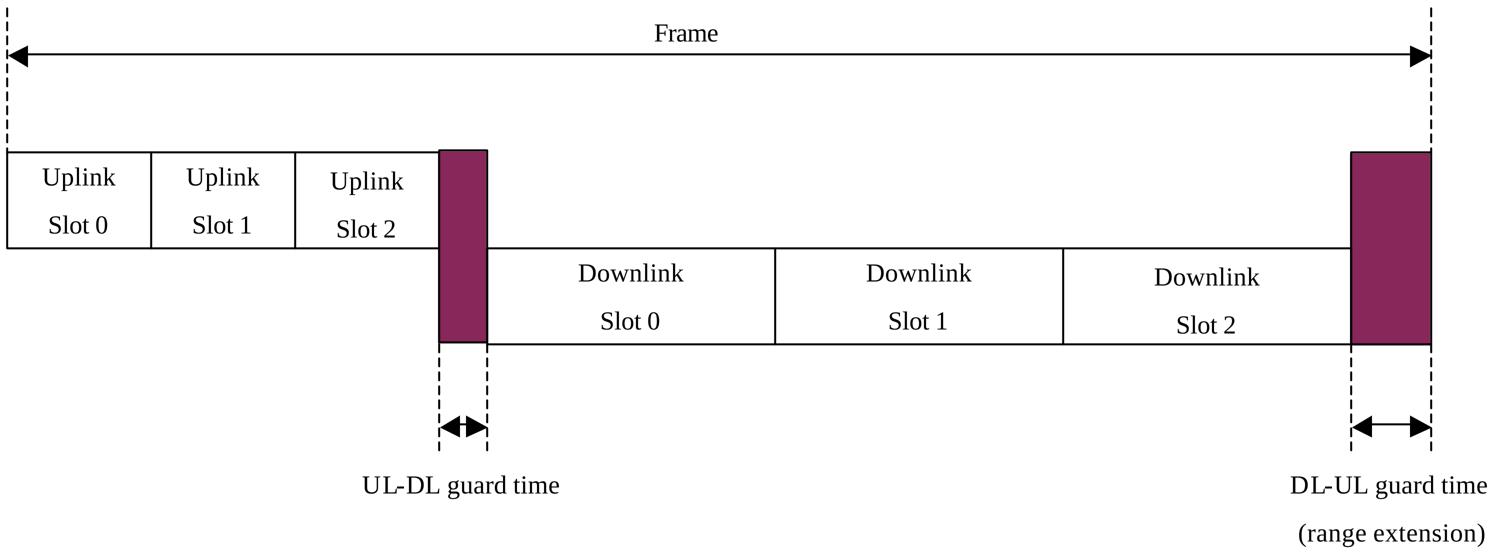
Multi Access with Adaptive Antenna Enhanced TDD/TDMA

- **Multi-carrier TDD/TDMA well suited for adaptive antenna array technologies**
  - TDD
    - The BS can estimate the channel to each UT prior to sending its downlink
    - Reciprocity of UL and DL channels has many advantages
  - Multi-carrier
    - Narrowband channels
      - Number of Transmitting Users seen by BS appropriate to Adaptive antenna Degrees of Freedom
      - Flat characteristics accross channel
      - flexible deployment
    - Carriers can be aggregated for increased data rate
  - TDMA/SDMA
    - SDMA techniques work well in a TDMA framework with protocol support
    - Adaptive antenna arrays reject out-of-cell interference

Adaptive antenna array technologies complement multi-carrier TDD/TDMA air interfaces

Multiple Access: TDMA Frame structure

A frame structure that exploits multiple BS antennas:



- UL slots before DL slots
- UL, DL slots are paired
- Short duplex period
- Not too many users/carrier

Multiple Access: TDMA Frame structure

- **Uplink: exploits adaptive antenna array techniques**
  - Spatial multiplexing (SDMA) of co-channel users
  - Rejection of inter- and intra-cell interference
  - Estimation of parameters for each UT
- **Downlink: exploits reciprocity**
  - UL and DL slots are paired
  - Short duplex period enhances reciprocity between UL and DL
  - SDMA and interference rejection are reciprocal when the UL and DL channels are reciprocal

Burst-by-burst processing of both uplink and downlink is robust to rapidly changing interference

Multiple Access: Burst structure

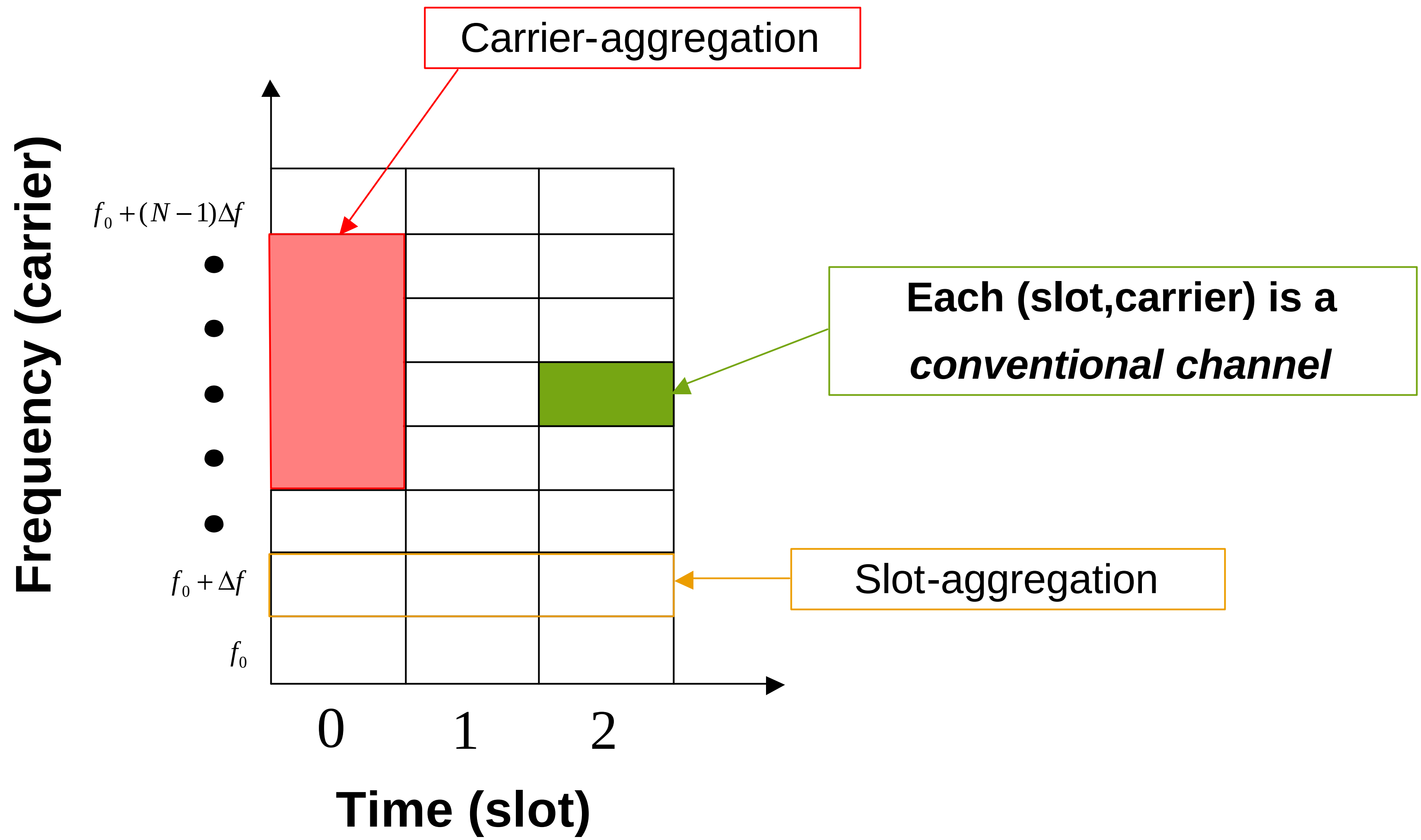
- **A training sequence (TS) should be present in every burst**

- **Training sequences should be unique within a "neighborhood" on each conventional channel (slot, carrier)**
  - Unique for each BS
  - Unique for each "spatial channel"
  - Unique for random access bursts
  - MAC layer assignment of TS

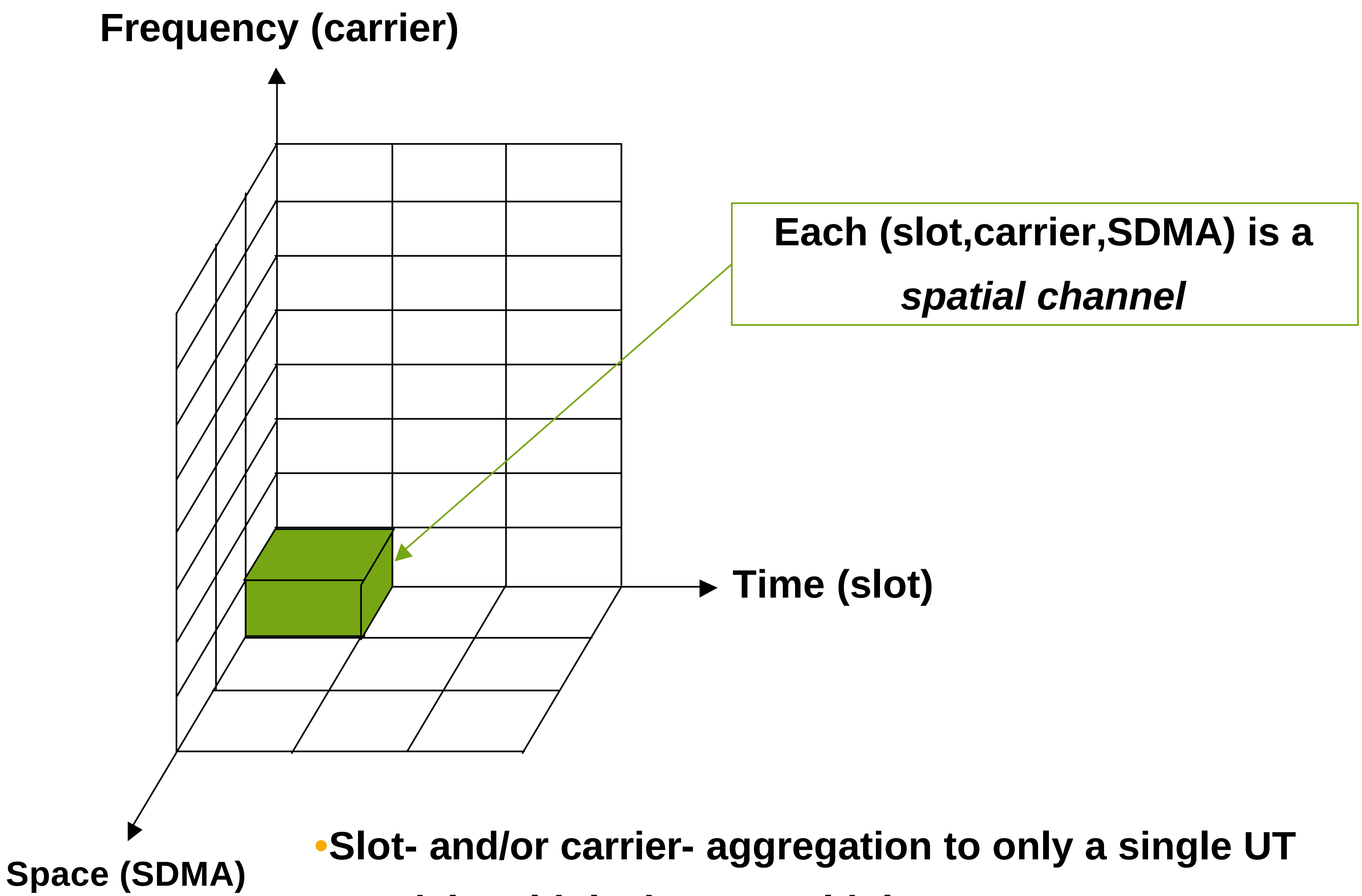
- **Training sequences should have good properties for estimation**
  - Sufficiently long for the expected number of BS and UT antennas
  - Small cross-correlation

Assignment of training sequences impacts the design of the MAC

MAC Resources: Multi-carrier TDD/TDMA



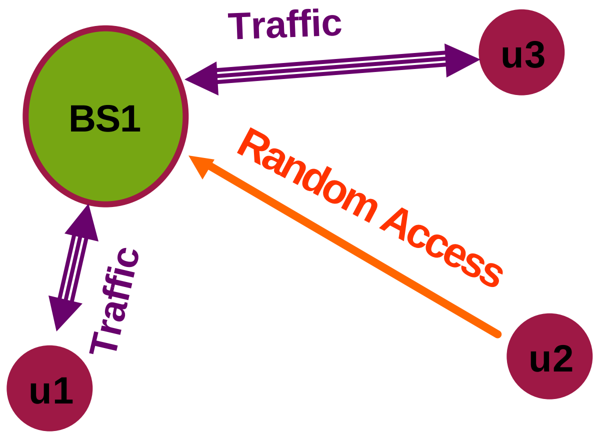
MAC Resources: Multi-carrier TDD/TDMA with Spatial Channels



- **Slot- and/or carrier- aggregation to only a single UT**
- **Spatial multiplexing to multiple UTs**

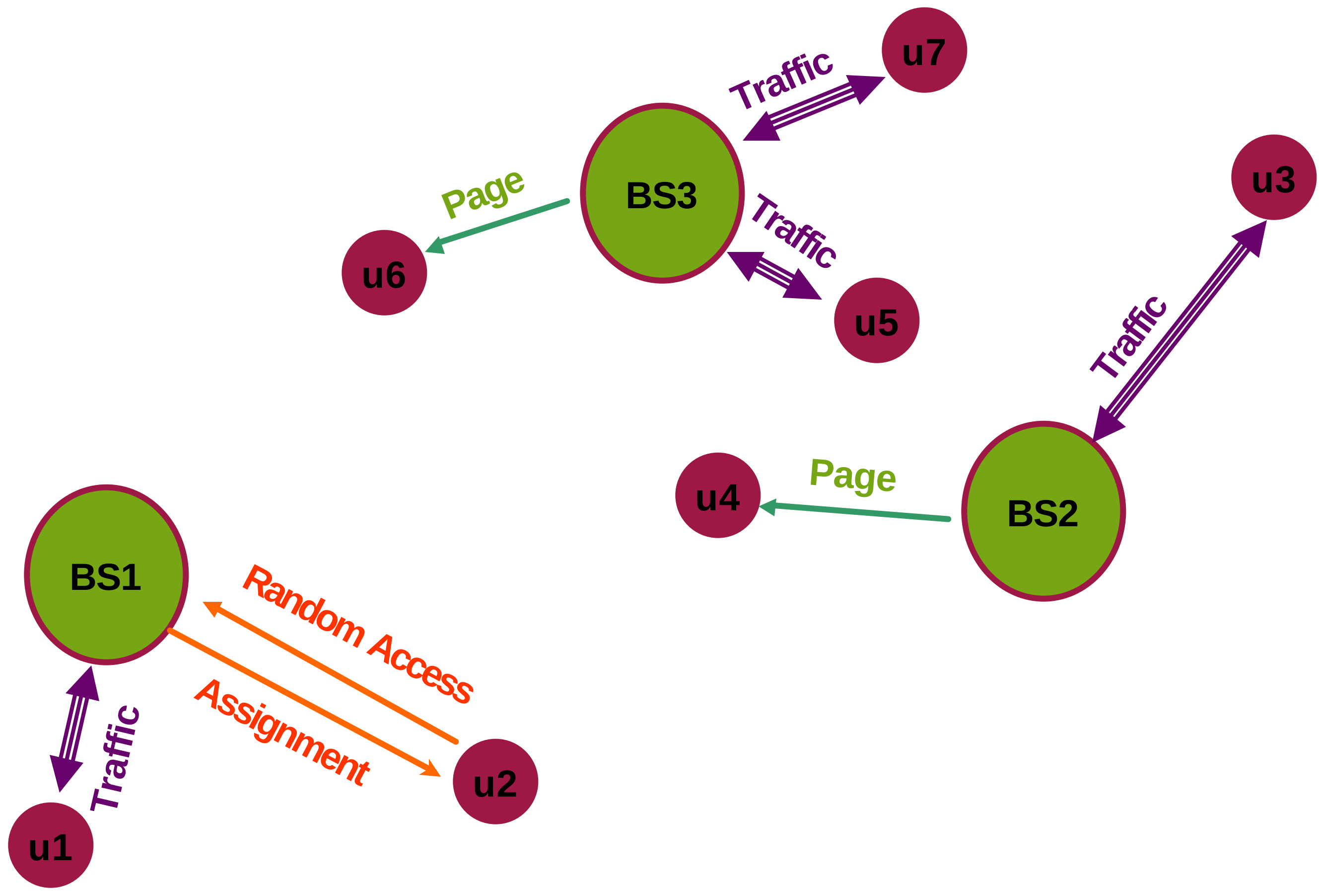
Shared Access and Traffic

BS resolves access and traffic spatially without packet error.



An Efficient MAC with Adaptive Antenna Arrays

A MAC that is tightly coupled to the multiple-access mechanism can multiplex control and traffic on a single carrier



MAC Design for MC-TDD/TDMA with Spatial Channels

- **All air interface resources contribute to good spectral efficiency**
- **The MAC must treat the resources separately**

  Examples:
  - Spatial multiplexing is only appropriate between different UTs
  - Time- and carrier-aggregation is appropriate to a single UT
- **Traffic scheduling**
  - Co-channel users can be spatially multiplexed
  - Resource allocation must consider spatial resolvability
- **Collision avoidance**
  - Simultaneous random-accesses do not necessarily result in collisions with adaptive antenna array techniques
  - Shared access and traffic

Suggests joint design of MAC and PHY

MAC/PHY Coupling: General Considerations

- **Physical resource properties dictated by PHY technologies**
  - Spatial channels
  - Codes, Tones, etc.
- **MAC creates services by allocating physical resources**
- **Quality of services is constrained by the physical resources**
  - Throughput
  - Latency
  - Jitter
  - Reliability
- **MAC should allocate resources based on specific PHY resource properties and constraints.**
- **General MAC solution that optimizes resource allocation for all possible PHY technologies seems difficult and complex.**

The high level of performance demanded by the PAR is much more easily met with a jointly designed MAC/PHY

Conclusions

- **Adaptive Antenna Arrays are provide benefits at both the PHY and MAC layer.**
- **Spatial collision resolution capability allows for the design of new class of high performance MAC.**
- **Significant advantages to design of MAC with PHY considerations in general.**

Recommend joint design of MAC and PHY within the MBWA working group.