Analysis of
Simple Infrastructure Multihop Relay Wireless System

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Base Document:

Purpose:

Information for discussions on the future work areas for multi-hop relay support for 802.16

Analysis of Simple Infrastructure Multihop Relay Wireless System

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Variations of Infrastructure Multihop

- forwarding links in different dedicated spectrum/Radio
  - Becomes Economic and deployment engineering problems.
    - Enhancements on Conventional wireless backhaul
  - Dedicated spectrum cannot be used flexibly
    - Thus, cheaper spectrum at high frequencies are often used for backhaul.

- Same spectrum for backhaul and user links
  - Same type of radio technology (e.g., all WiFi meshes)
  - Most flexible: Dynamically used in time/frequency/code/tone, etc..
  - Concerns on Capacity Hit compared to conventional systems with same amount of spectrum
    - Must control resource consumption for backhaul
      - Number of hops, modulation efficiency, etc..
- Analyze a simple system to identify basic features needed in standards

Backhaul vs. Tower leasing

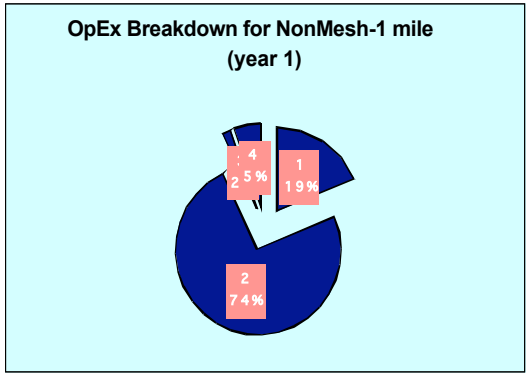
- The cost of electronics goes down but the cost of civil engineering, site acquisition & laying fiber remains very high.
- Non MMR:
  - High Backhaul cost & High or Low Tower Cost (depends on cell Radius)
- MMR(6 to 1 cell aggregation):
  - Backhaul (Aggregation) & Low Tower cost (cell radius small)
- Tower related cost become more important as backhaul cost go down

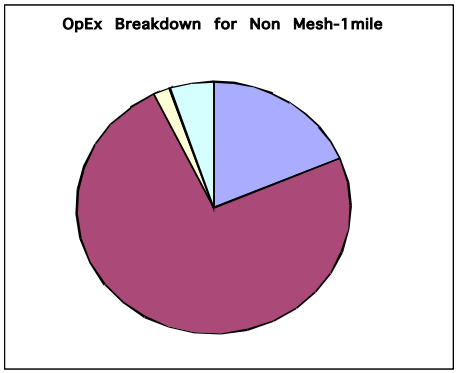
1 → Tower Leasing

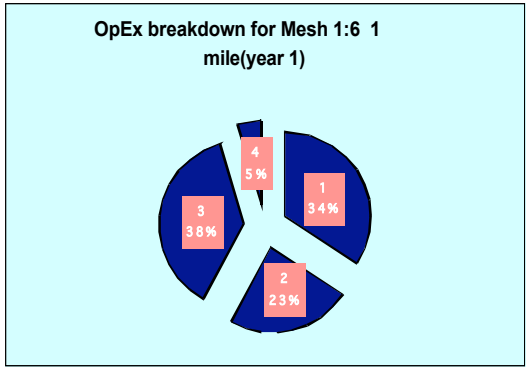
2 → Backhaul facility

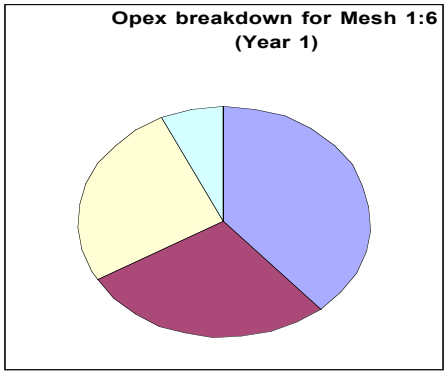
3 → Customer Acquisition and CPE Subsidy

4 → Maintenance









Assumptions

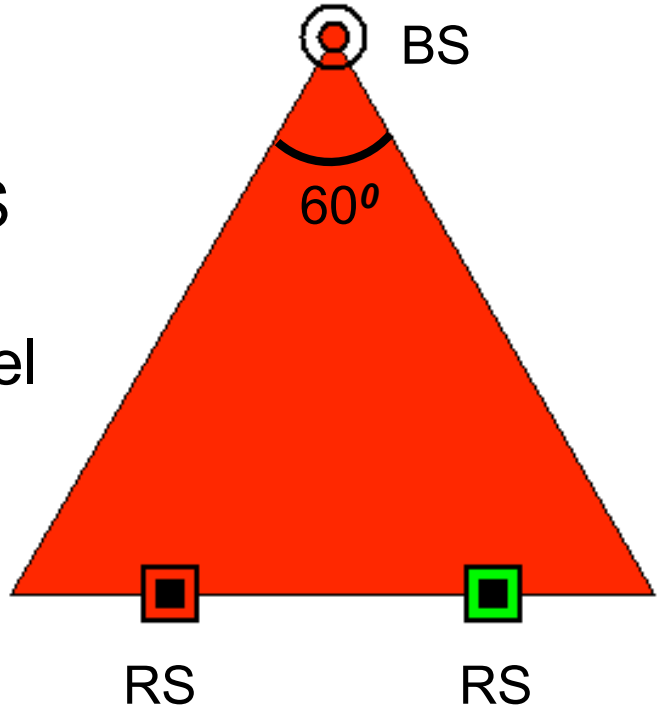
- Time-shared "centralized MAC" packet radio system
  - 802.16/WiMAX OFDM(A)
  - CDMA EV-DO, UMTS HSDPA
- Equal time per SS under uniform infinite offered traffic
  - Scheduling considerations later, perhaps outside of 16
    - Except measurements to assist scheduling decisions
- Two-hop infrastructure system
  - For now.. Lower complexity and cost
  - Most gain achieved by the first additional hop
    - due to exponential nature of propagation
    - Also in "On the throughput enhancement of ….. multihop relaying" Jaeweon Cho; Haas, Z.J., JSAC, V 22, I 7, Sept. 2004, P 1206 – 1219

Assumptions

- "Low complexity" RS
  - Smaller and lower height than BS, but higher than SS
    - Infrastructure RS
  - Single radio communicating with both SS and BS
  - Omni directional antenna to serve SS
  - Similar complexity as SS except
    - May use Directional antenna for RS-BS link
    - Alternate between antennas using simple switch
- Capacity Limited system
  - Coverage advantage is obvious and previously studied
  - Examine the hit on user traffic capacity due to multihop relaying

Mesh Sector

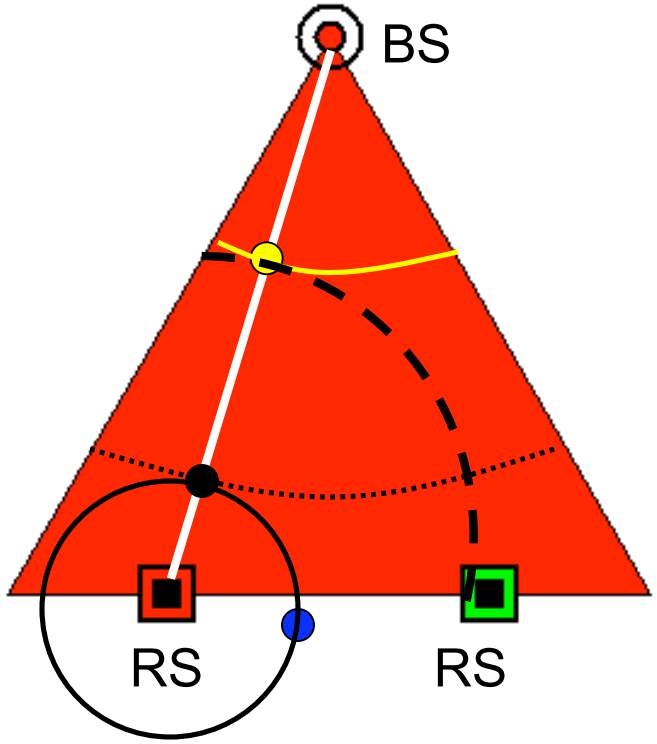
- Place RS near Sector boundary
  - Omni for RS
    - Symmetric, Simple, Shorter range.
  - Maximum benefit in terms of path gain
    - With smallest number of RS with Omni antenna
- Red RS using the same RF channel as the supporting red BS
  - Same reuse pattern as conventional systems
- Green RS belongs to the facing sector
  - Can switch sectors depending on load



Simple Analysis

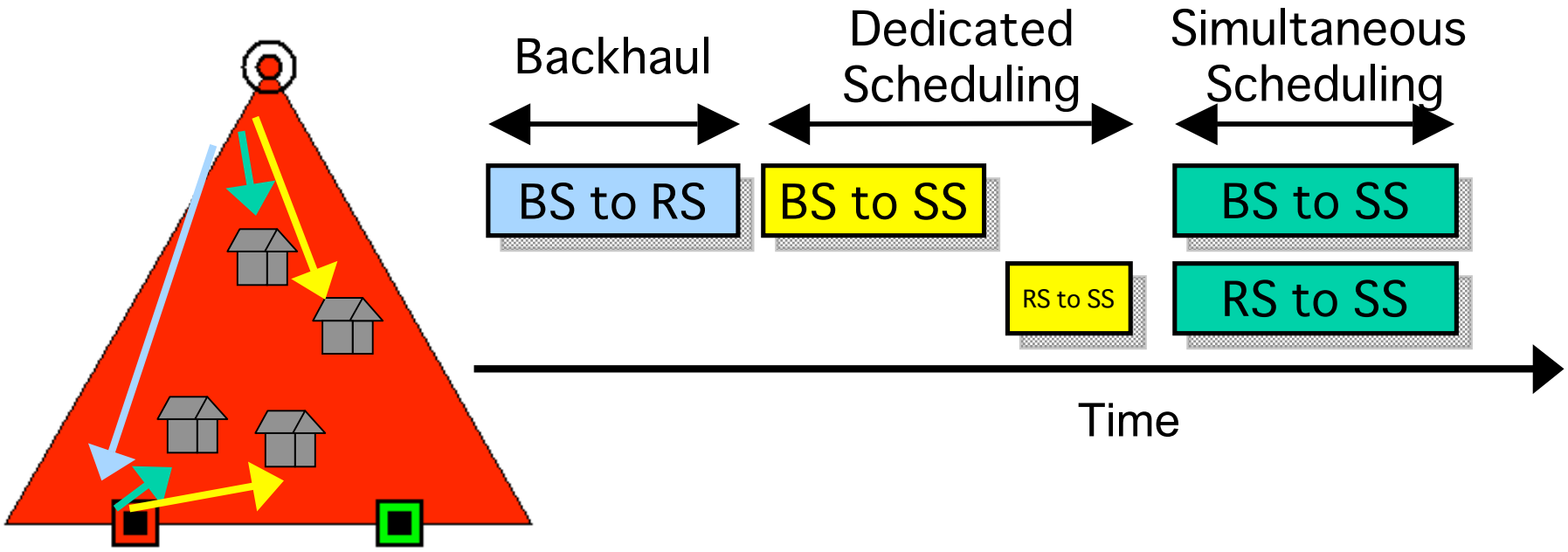
- Resource reuse feasible?
- If so, Sector throughput gain?

- Analytical formulation for worst case multi-cell arrangement indicates “Yes” to both questions.

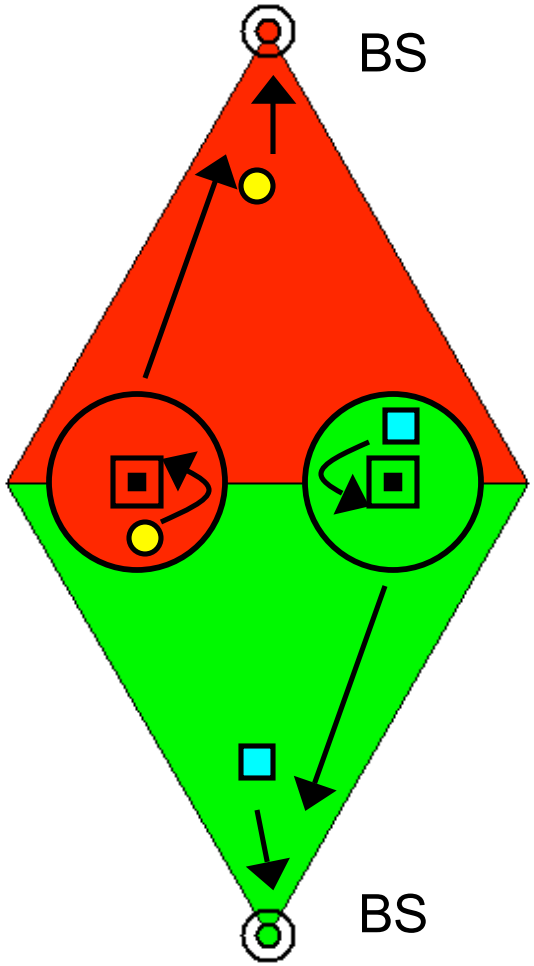


Intra-Sector Scheduling Approach

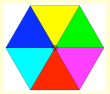
- Compatible with 802.16 PMP frame structure
  - One possible frame structure



Mesh Sector Analyzed



Simulation Parameters

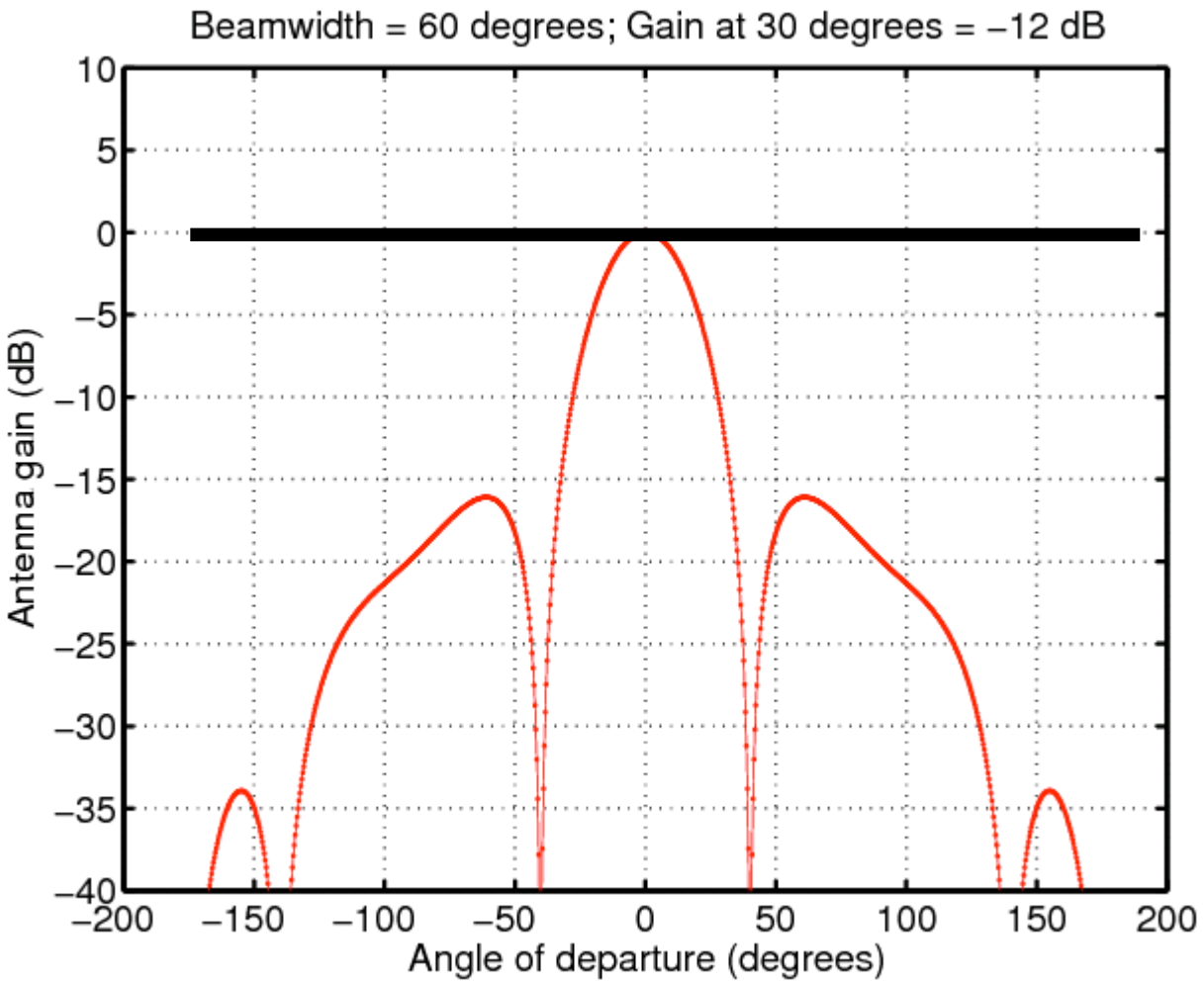
Frequency reuse	(1,6,6)  & (1,3,6)
Cell radius	1000 m
BS gain	20 dB
RS gain	0 dB
BS height	30 m
RS height	15 m
SS height	2 m
Transmit power	30 dBm
Power control	No, for now
Path loss model	Erceg-Greenstein (aka. 802.16 model)

Simulation Parameters - Rates

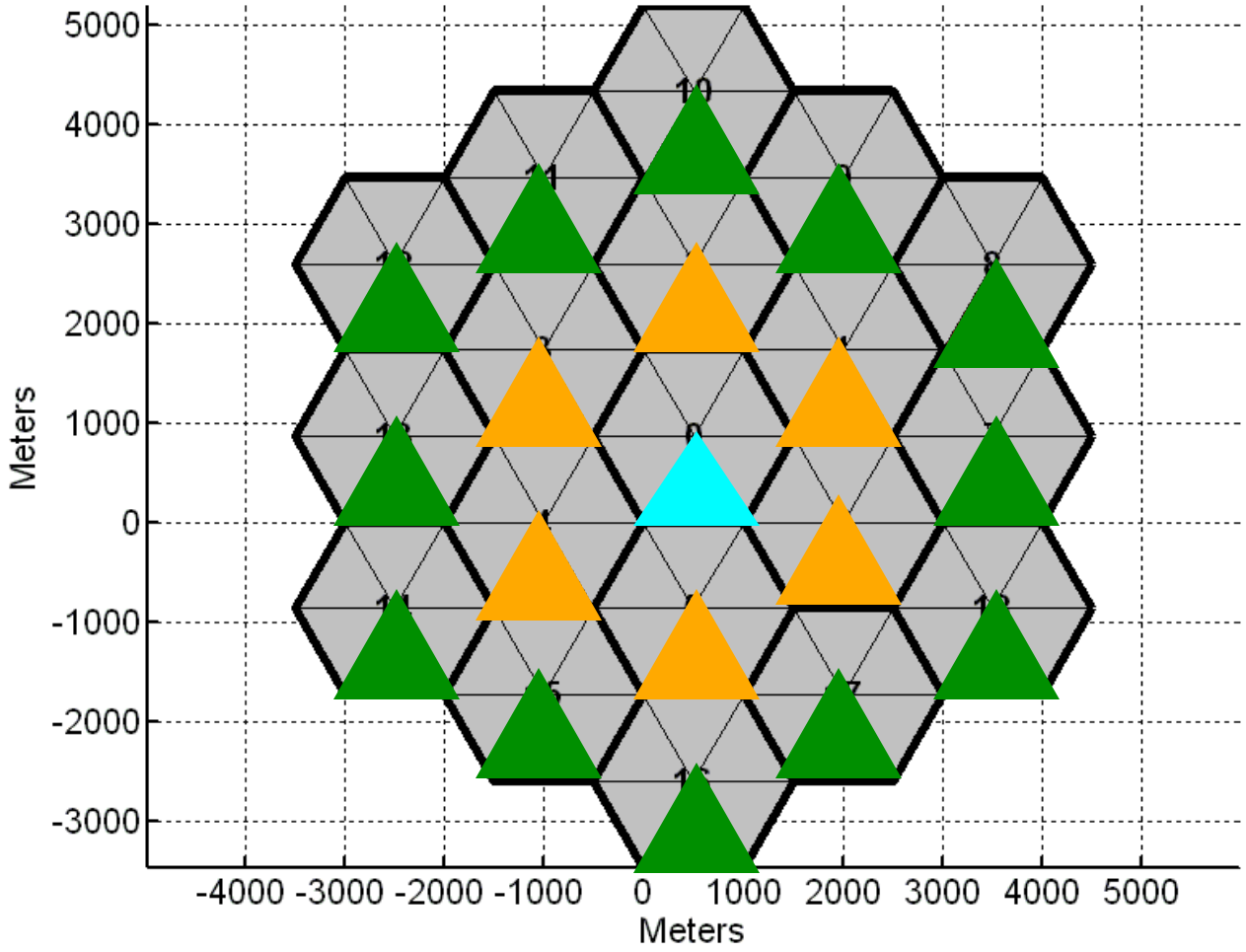
- 6 MHz channel
- Representative values for 802.16/WiMAX
  - Continuous capacity analysis tends to be optimistic
  - Lower yet more robust rates are available but not simulated.

Modulation	Code Rate	Required SINR (dB)	Data Rate (Mbps)
QPSK	1/2	6.6	6.0
16-QAM	1/2	10.5	12.0
64-QAM	2/3	15.3	24.0
64-QAM	3/4	20.8	27.0

Directional Antenna Pattern

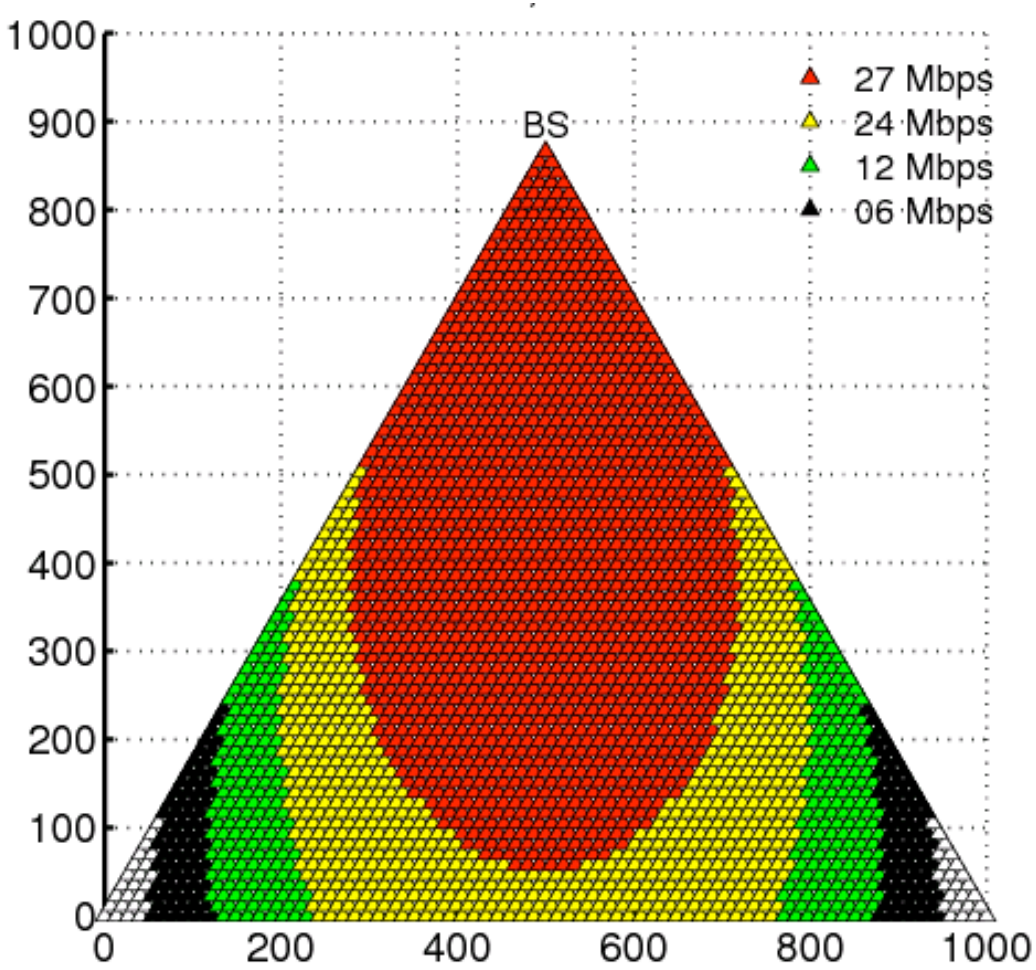


Multi-Cell Scenario without RS Reuse pattern (1,6,6)



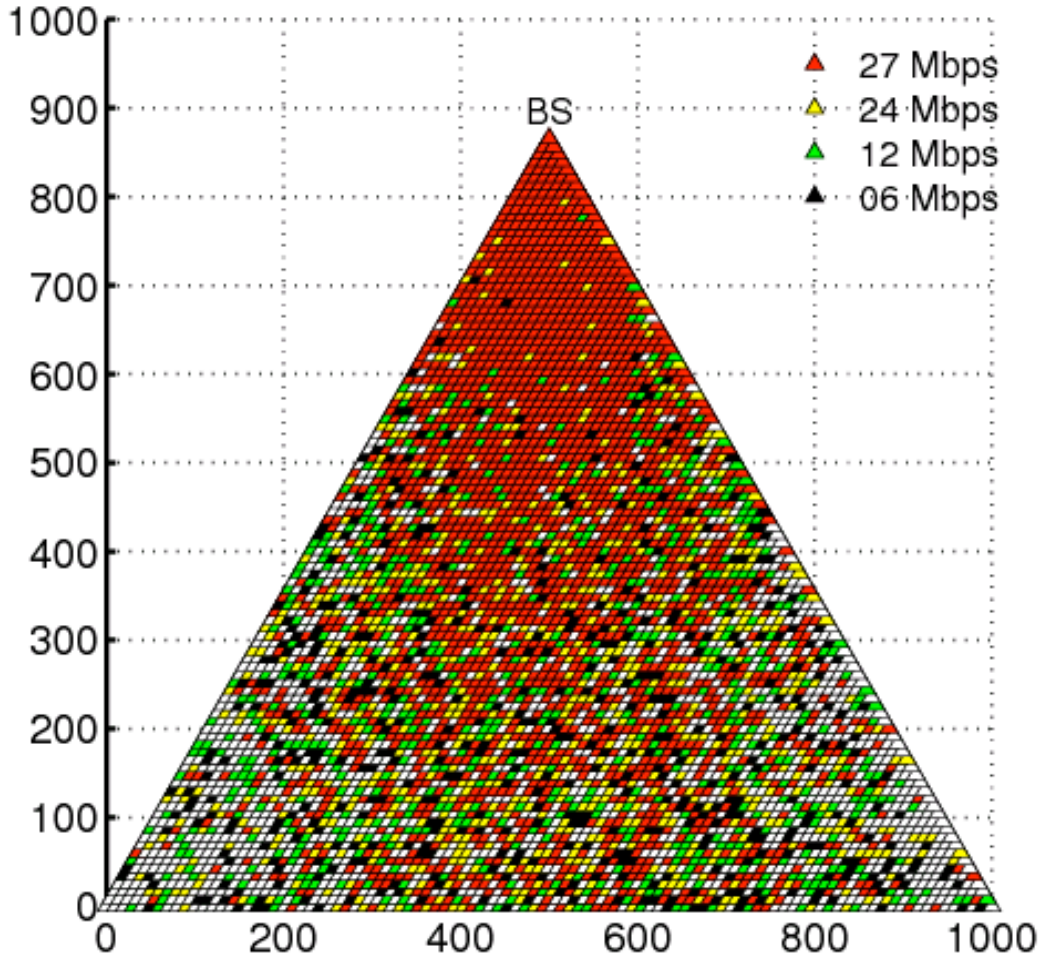
Multi-Cell Scenario without RS

- No log normal fading

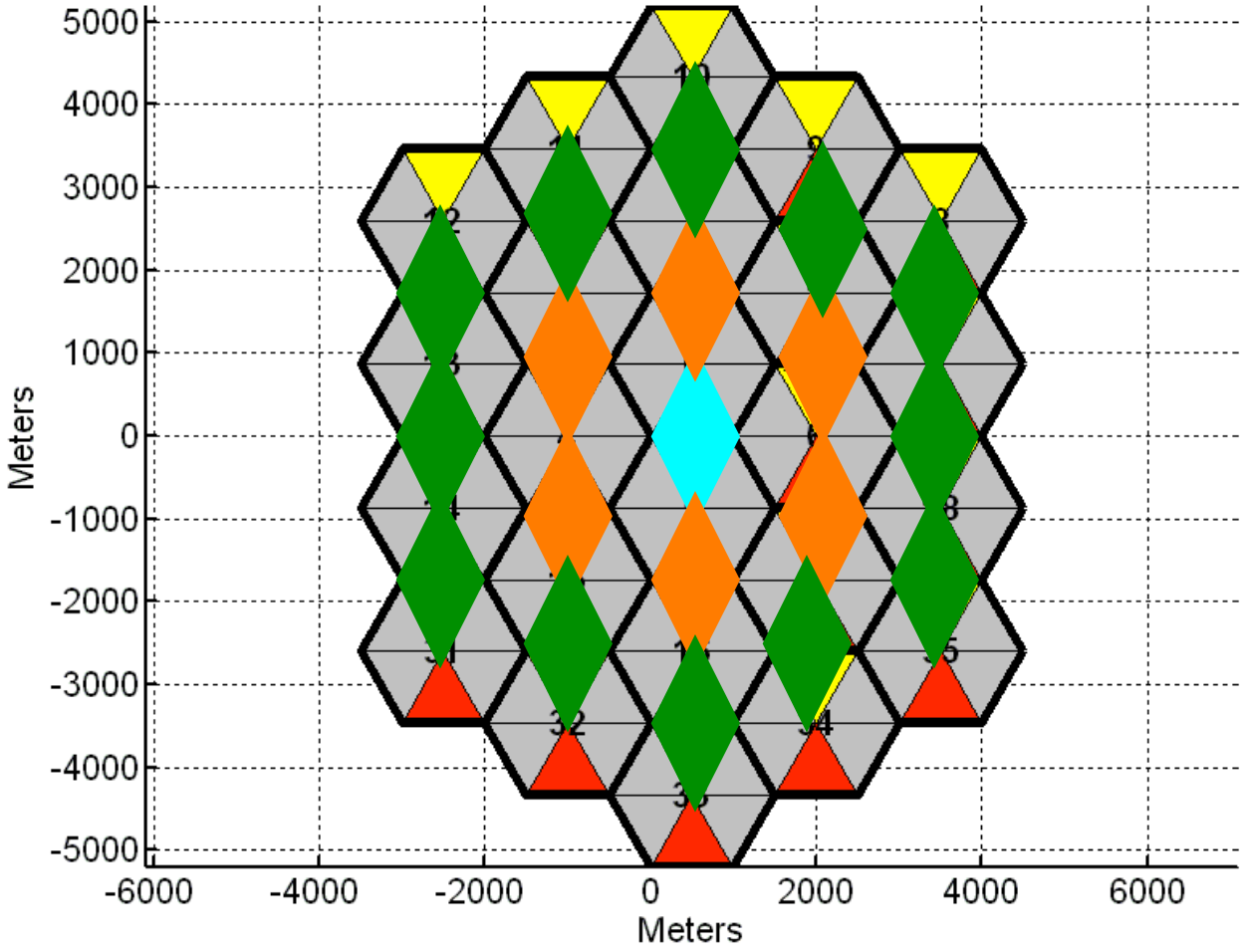


Multi-Cell Scenario without RS

- With log normal fading

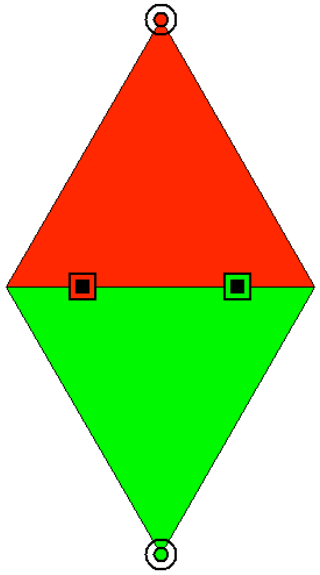


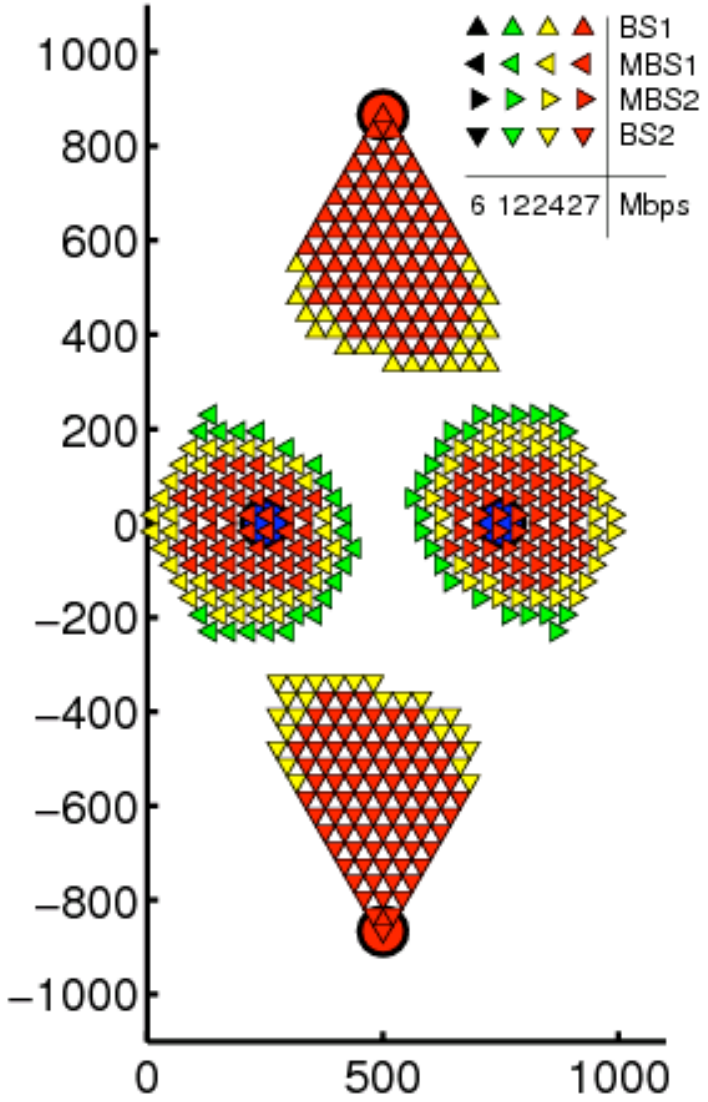
Multi-Cell Scenario with RS Reuse pattern (1,6,6)



Multi-Cell Scenario with RS

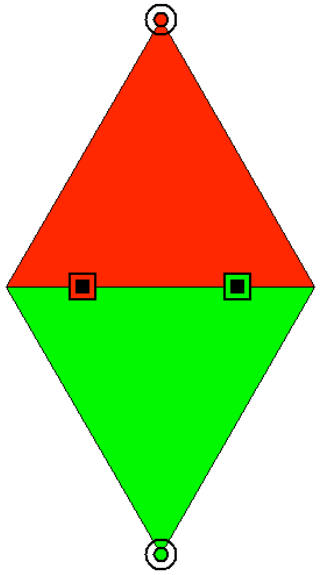
- No log-normal fading
  - For illustration
- Simultaneous scheduling regions

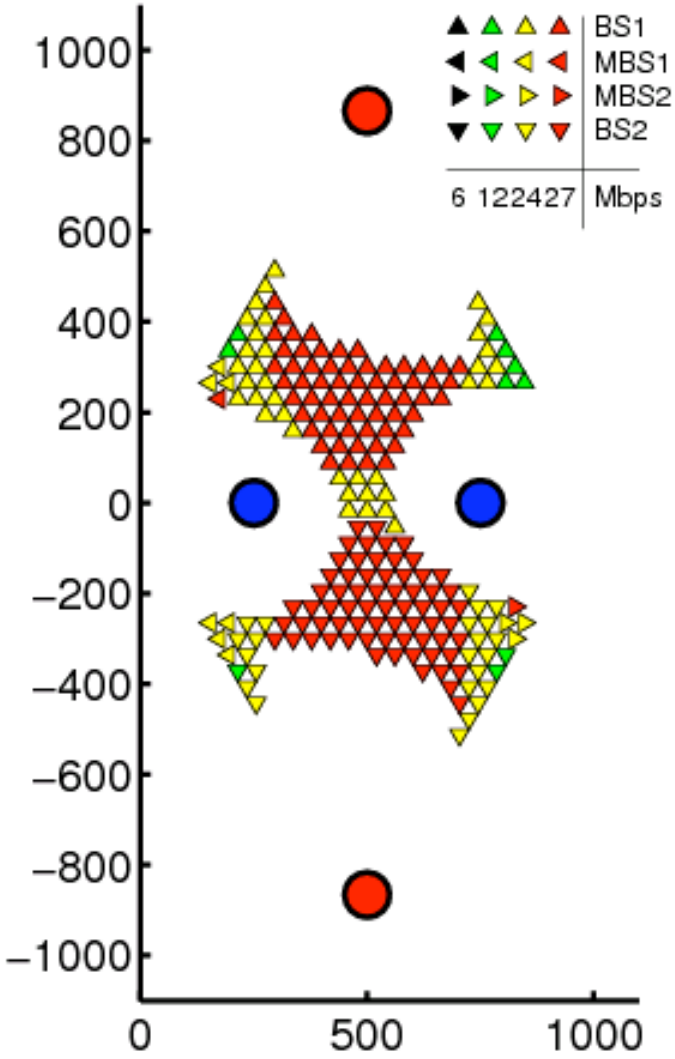




Multi-Cell Scenario with RS

- No log-normal fading
  - For illustration
- Dedicated scheduling regions

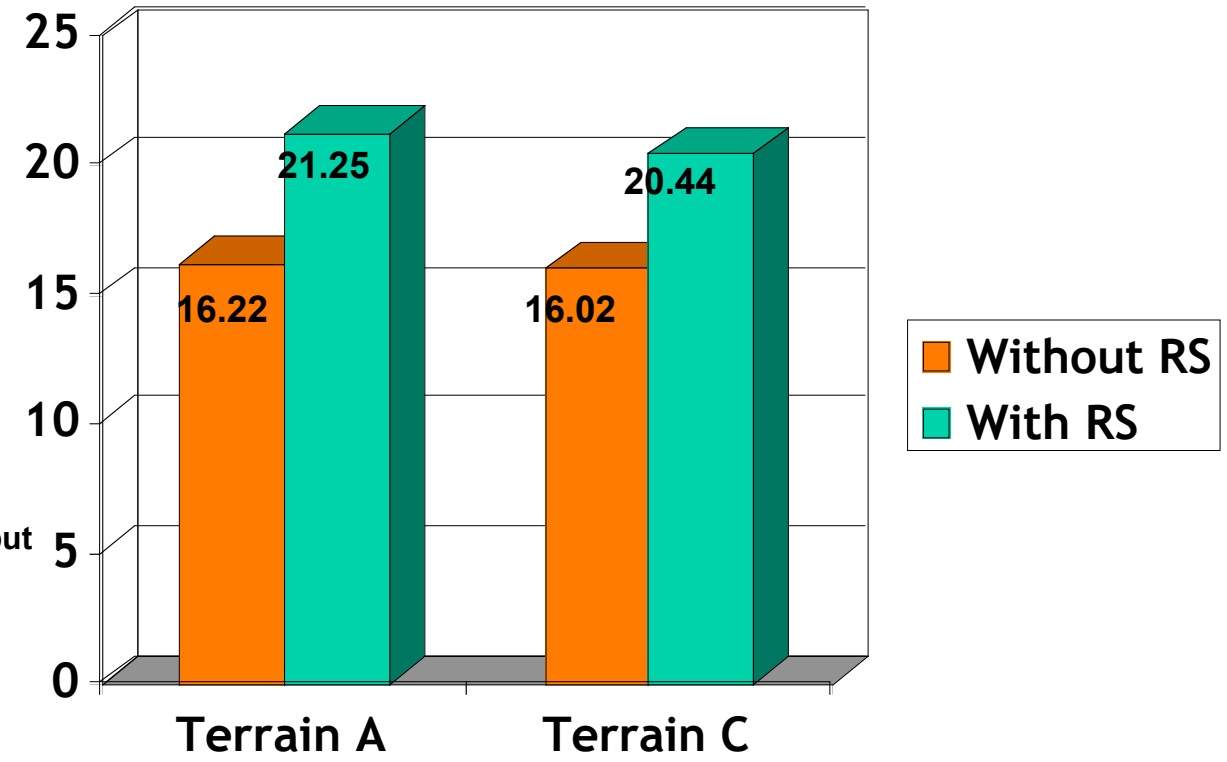




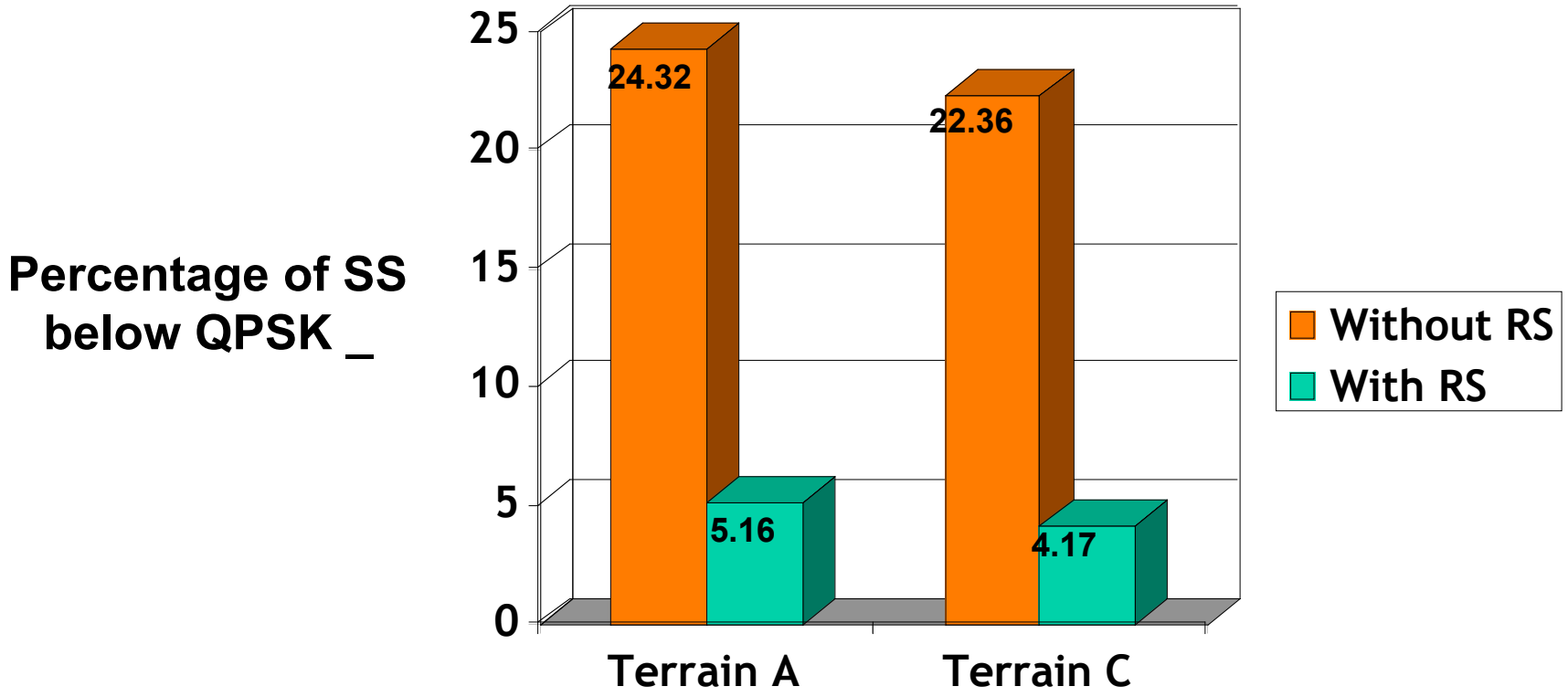
Throughput Comparison: (1,6,6)

User traffic Throughput Per sector (Mbps)

Excluding forwarding throughput

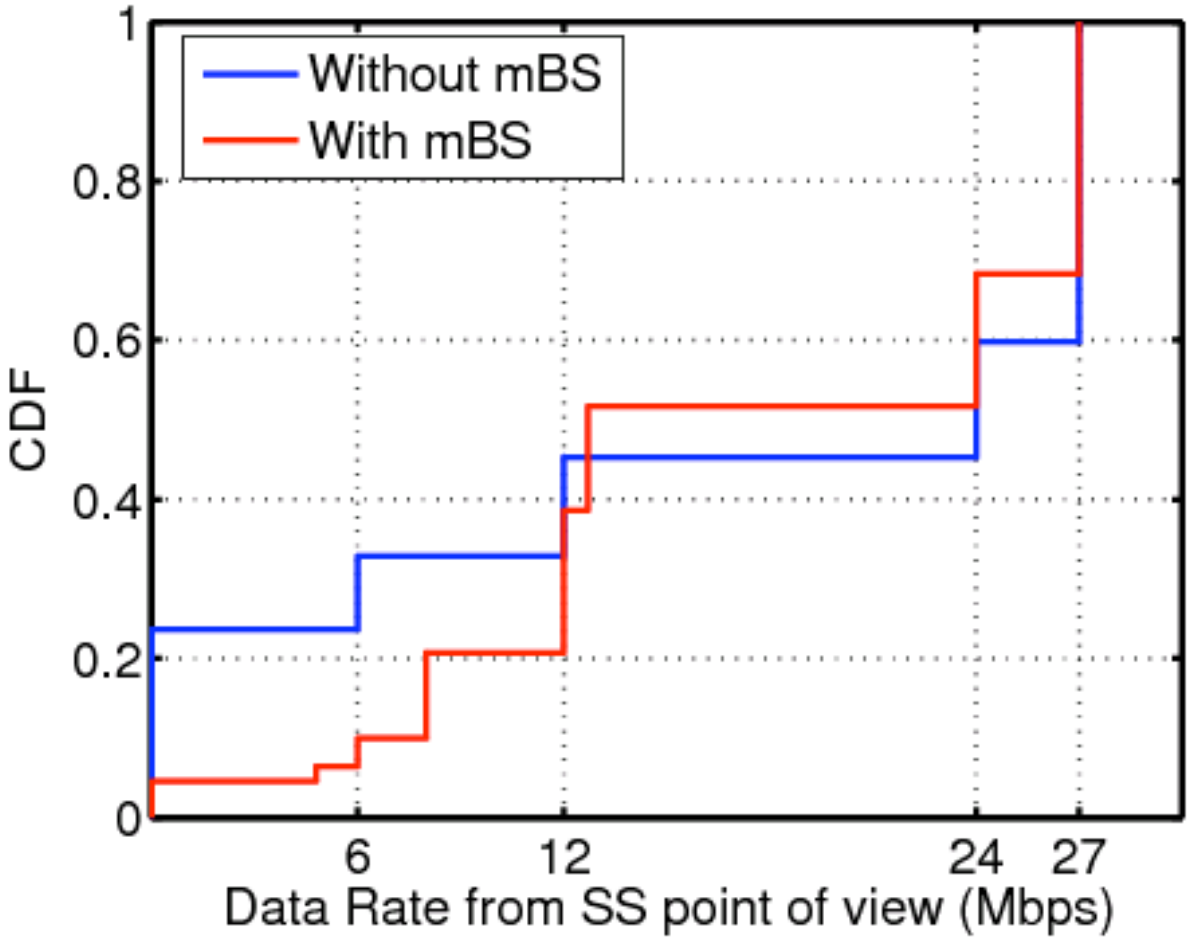


QPSK _ Outage Comparison (1,6,6)



Obviously, Capacity and Coverage interplay,
but the conventional system needs larger reuse distances to match the RS system.
Thus. the capacity gain in the previous slide is in fact higher.

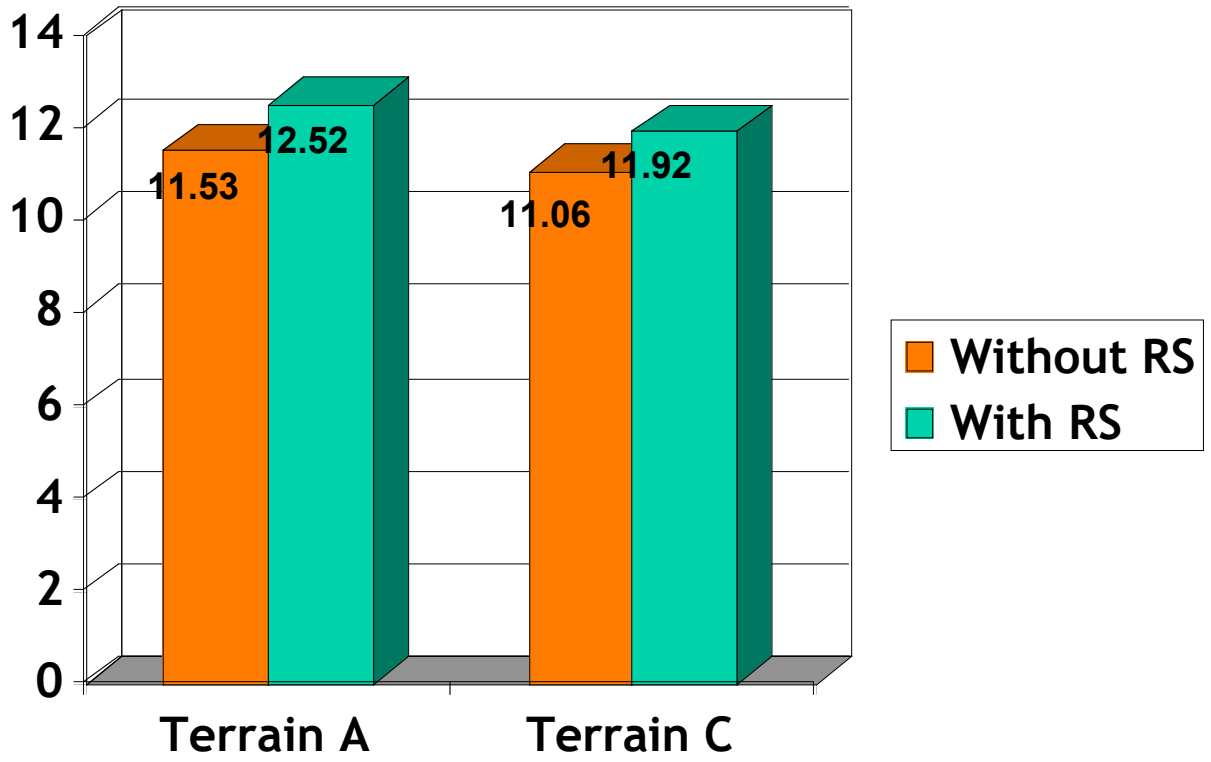
SS Data Rate Comparison



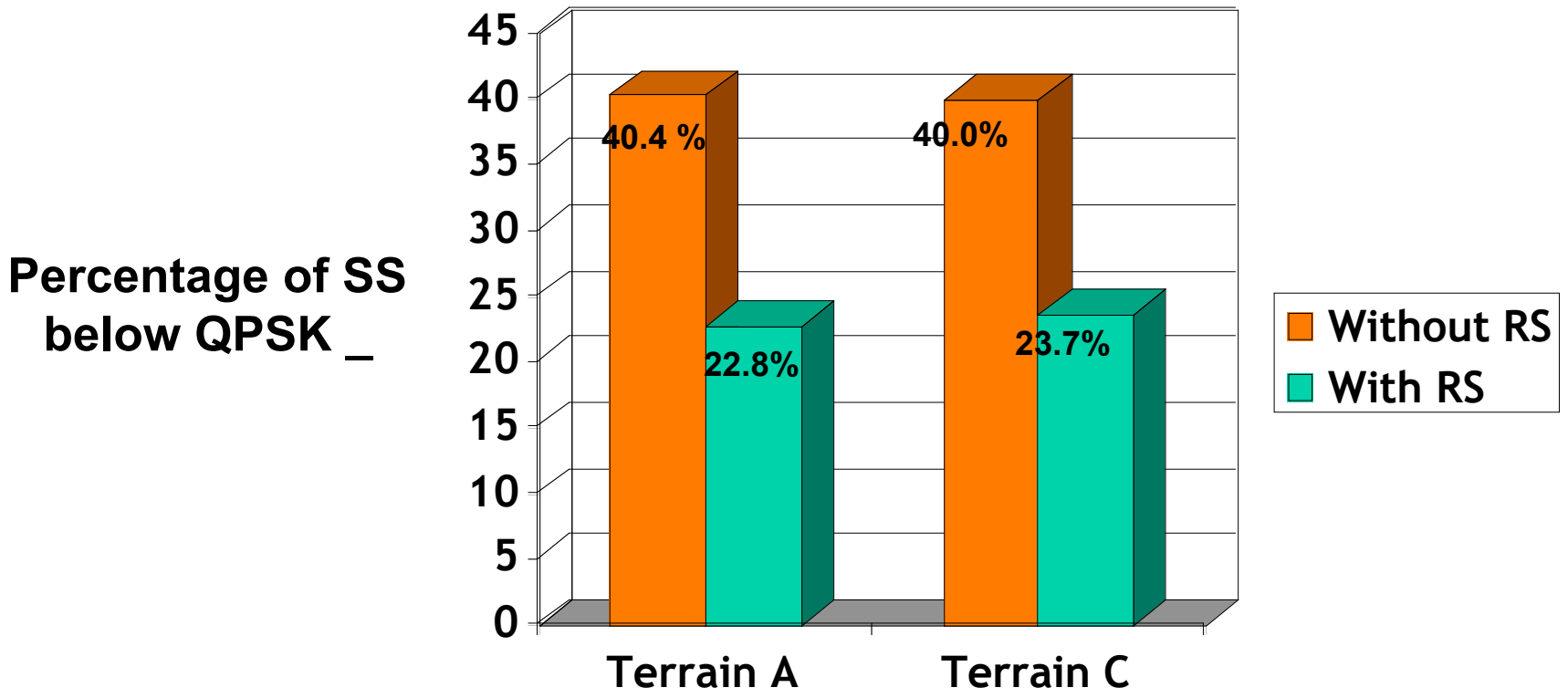
Throughput Comparison: (1,3,6)

User traffic Throughput Per sector (Mbps)

Excluding forwarding throughput



QPSK _ Outage Comparison (1,3,6)



Conclusions

- (1,6,6) system with 6 mBS per cell shows:
  - QPSK _ Outage improvement around 80 %
  - Overall sector throughput improves from 16 Mbps to 21 Mbps
- Less Gains under more severe interference situations: e.g., (1,3,6)

- Capacity improvement in multihop forwarding system more than compensates for radio resources diverted towards RS - BS Link
  - If simultaneous scheduling is supported.
  - Without sophisticated interference management

Implications on PAR/5C & Future Work

- Smaller Scope is more realistic for quick standardization
  - Basic well-understood toolkit for multiple scenarios and solutions
  - Limit to infrastructure fixed/nomadic RS?
    - Less impact on SS, but don't impose "don't touch SS" requirement
    - Provides large and immediate benefits in coverage and economics
  - General solution for arbitrary number of hops is harder than 1 or 2 additional hops? Too restrictive?
  - Additional PARs for further scenarios as current draft solidifies
    - Perhaps 2 or 3 PARs needed in staggered time schedule
- Mechanisms to support intra-sector spatial reuse
  - Channel/Interference measurement mechanisms: Examine existing methods and extend
  - Scheduling/Identification mechanisms

Implications on PAR/5C & Future Work

- Layer 2 routing remains transparent to SS Host OS.
  - Consider (M)RSTP from 802.1, though may not be optimal
    - Request extensions to 802.1?
  - Channel condition assisted routing decisions
    - e.g., “is RS-BS link fast enough to bother?”
- Multihop CID management
  - More compatible to 802.16, but scope, uniqueness, conflict, aggregation, assignment
- or MAC address inside BS-RS links?
  - Simpler routing and identity management, but overhead.
- Scheduling coordination among RS and BS?
  - Fragmentation and buffering btw two hops
- BS and RS may appear as BS to SS
  - If BS MAP controls all, coverage extension limited, but simpler?
  - ARQ independence for RS: Quicker turnaround
  - Better backward compatibility
  - Implications on the complexity of RS

Spellings suggested by PowerPoint

- Multihop ➔ Ultimo
- Saha ➔ Saga
- Erceg ➔ Erect (Erect-Greenstein model)
- dBm ➔ dam
- Shankar ➔ Shaker
- WiFi ➔ Wife