Higher Capacity through Multiple Beams using Asymmetric Azimuth Arrays

Intelligent RF for Enhanced Mobility

CDG Technology Forum
April 20, 2006

Presentation Content

- Brief Company Background
  - TenXc Wireless is new to CDG
  - TenXc Wireless focuses on Spectral Efficiency Solutions
- Concept Overview
  - Higher Order Sectorization
  - Multiple Beams using Asymmetric Azimuth Arrays
- Capacity Gain Simulation
  - Simulation Assumptions & Model
  - Simulation Method
  - Results
- Conclusion and Application

Company Foundation

Background

Established:	2002
Employees:	50+
Industry sector:	Wireless access infrastructure
Target customers:	Wireless service providers, OEMs
Investment to date:	US$18M

The Team

Experience: Wireless and telecom industry veterans (15% -PhD's, 30% - Masters), business, customer and technical backgrounds

Product

Product:	Intelligent cell site enhancement solutions
Technology:	Spatial processing, Adaptive Digital Beamforming, array antennas
Stage:	Operator trial ready

TenXc's Technology Portfolio

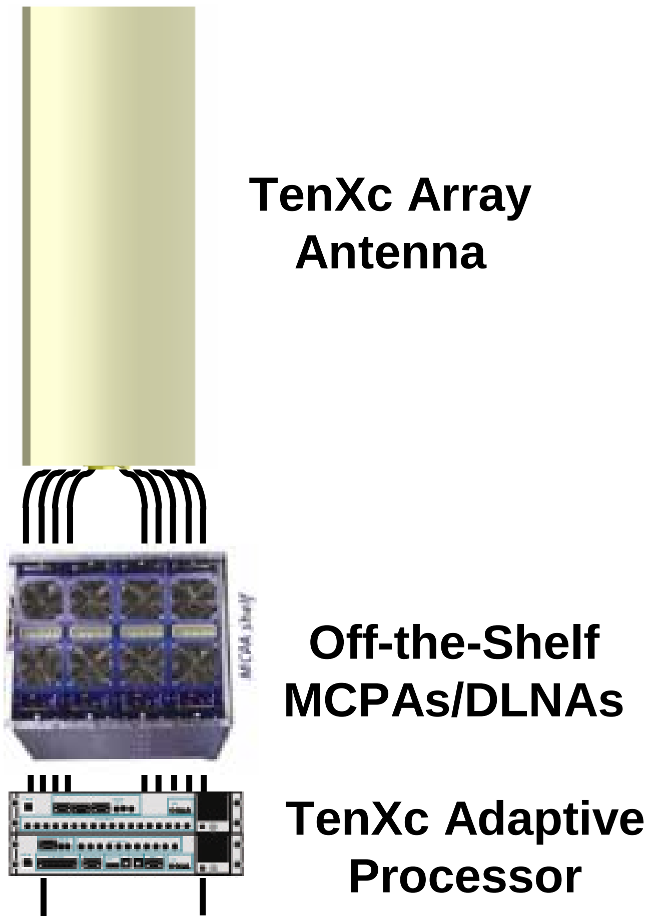
Array Antennas
- Asymmetrical patterns
- Polarization & angular diversity

Adaptive Digital Beamforming
- Adaptive null steering
- Adaptive beam shaping
- MIMO

Beam-Space Architecture

Propagation & Traffic Modelling
- Algorithm optimization
- Network planning tools

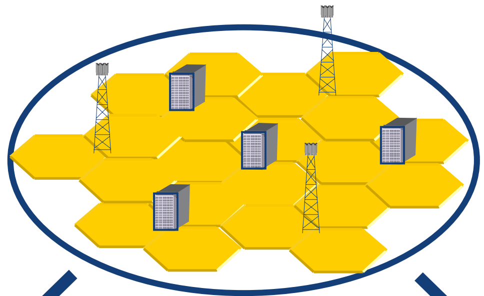
Active Antennas
- Distributed power architecture



Intelligent RF Approach

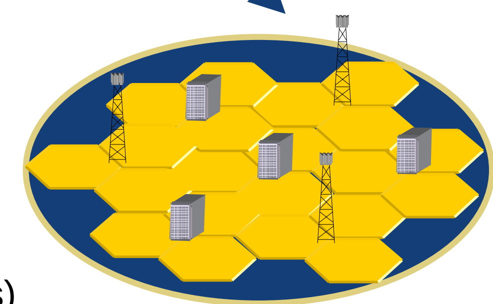
- Cell Site

Network Today



Conventional Approach
- Purchase new spectrum
- Add new sites, cell splitting

Intelligent RF Approach
- Increase spectral efficiency
- Maintain cell site plan



Future
(More Users)

- **Increased capacity and coverage**
- **Improved service quality**
- **Reduced network expansion costs**

Concept Overview

- Higher Order Sectorization
- Multiple Beams using Asymmetric Azimuth Arrays

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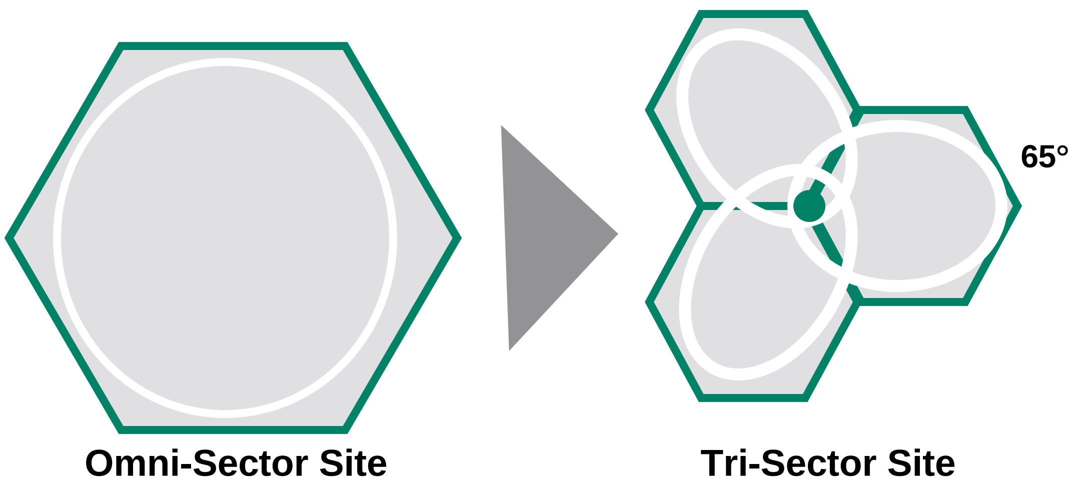
Higher Order Sectorization (HoS)

Higher Order Sectorization:

- Spatial subdivision of geographic coverage is the paradigm of “cellular” systems
- In general, the more sectors, the more spectrally efficient a system is
- However, there are practical limits

Common Practices:

- Standard designs use tri-sectored sites with 65º antennas
- Further sub-sectorization is not often used due to undesired RF overlap
- Often results in increased “softer” handoff rates which undermine the spectral efficiency gains.



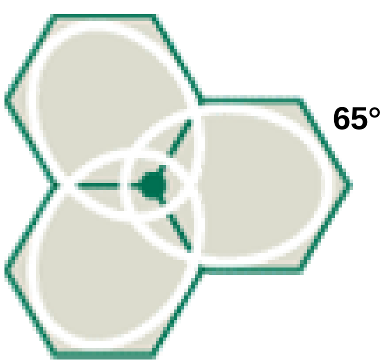
Higher Order Sectorization (HoS)

Solve the HoS Problem :

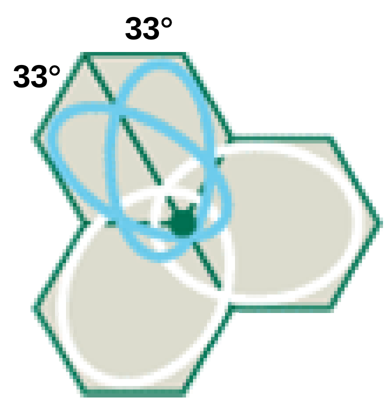
- Typical solution uses 33º narrow-beam antenna for HoS
- Problem is with sector-to-sector overlap
- Due to symmetrical shape of beam

New Method:

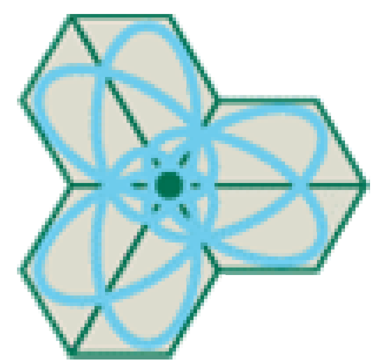
- Create a better narrow beam shape using array technology
- Control outer-edge rolloff and inner edge overlap – results in asymmetrical beam pattern
- Project two asymmetrical beams from single array to create optimal RF coverage for new HoS sub-sectors



Tri-Sector Site



Multi-Sector Site (4 sectors)



Multi-Sector Site (6 sectors)

Asymmetric Pattern Advantages

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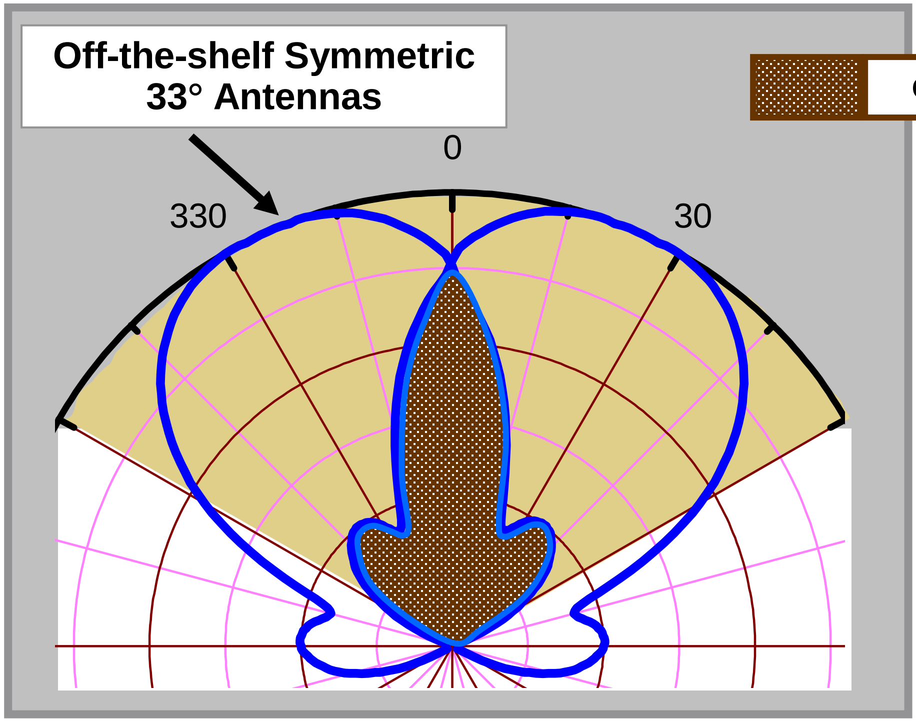
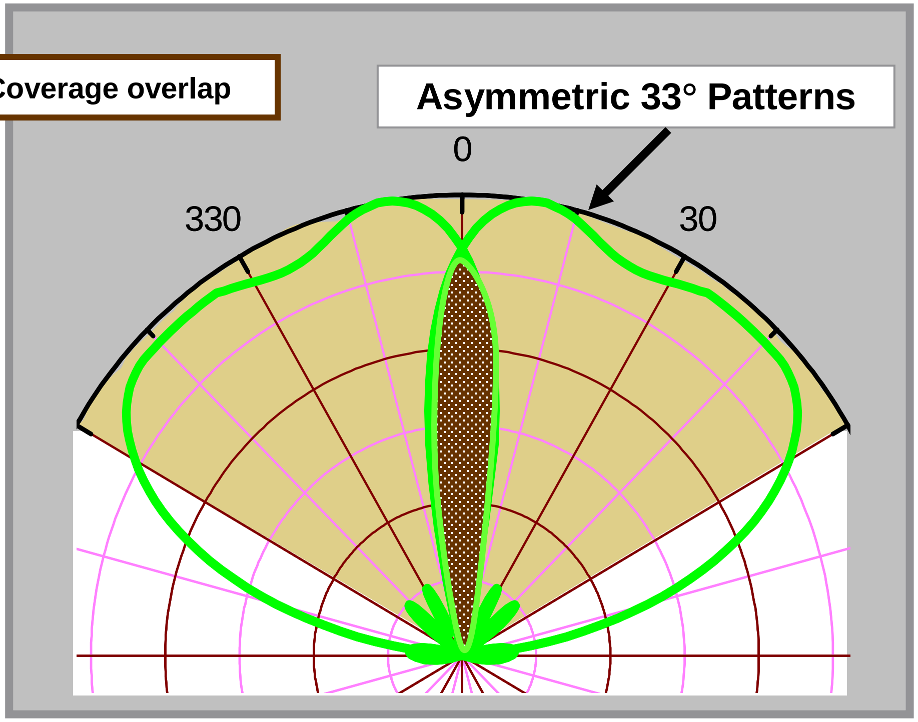
Conventional Multi-Sector



Excessive handoff overhead inefficiency with off-the-shelf antennas

"Bi-Sector" Array



Load balance, control interference, manage handoff overhead

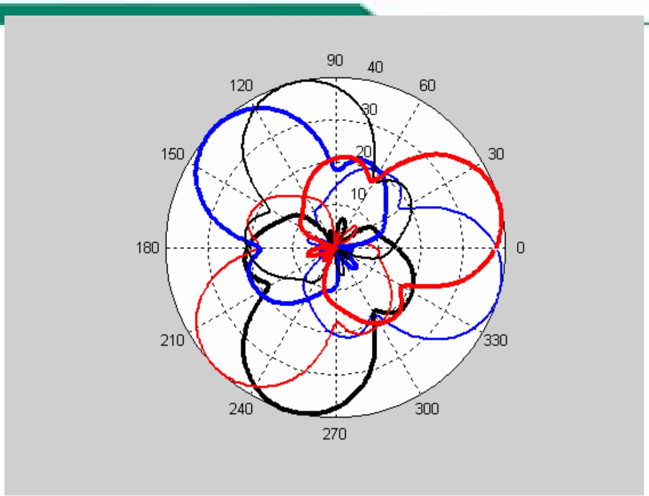
Optimize coverage and capacity

- Small adjacent sector overlap reducing softer handovers
- Better match of original tri-sector coverage

New HoS Solution

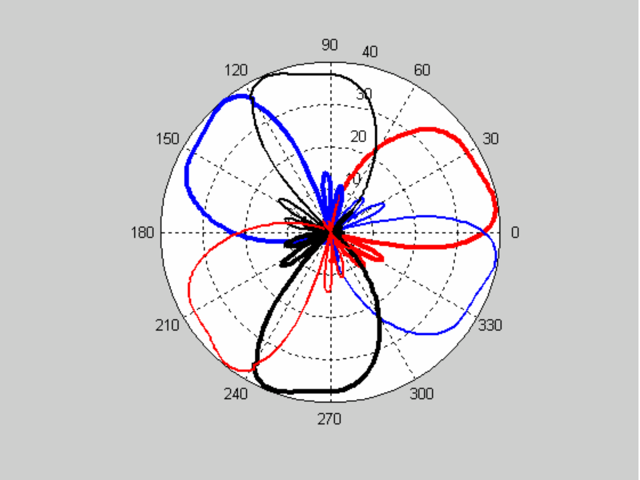
Compared to side by side symmetrical RF patterns, asymmetric patterns offer:

- Small overlap between adjacent sectors reducing the softer handoff rate
- Better coverage at the bore sight of the antenna array
- The best tradeoff of the above (coverage and overlap)
- Better match of old 65 deg coverage



Array Technology

- Allows for two asymmetric beams to be placed into single antenna structure for reduced antenna count
- Simplifies antenna alignment at deployment



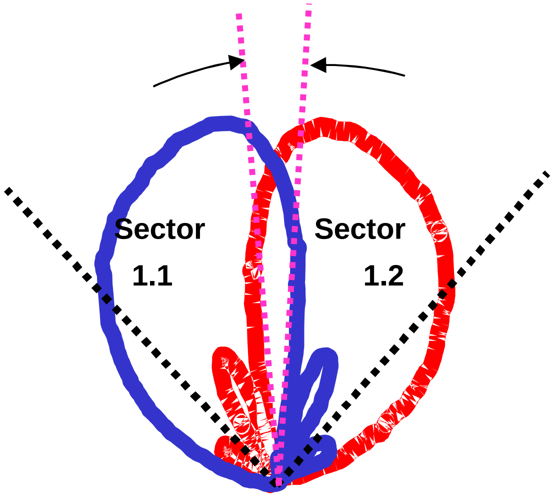
“Bi-Sector” Array

“Bi-Sector” Array

Multi-Beam Asymmetric Beam Approach:

- Single facet for dual sectors
- Asymmetrical (azimuth) patterns
- High gain array approach
- High performance sidelobe levels

Dual Sectors



Remaining Question:

- What is the actual spectral efficiency gain over standard 33º antennas?
- What is the impact on softer handoff?

Next we simulate the array performance to answer these questions.

Capacity Gain Simulation

- Simulation Assumptions & Model
- Simulation Method
- Results

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April 20, 2006

Purpose of the Simulation

- Simulate the performance of 1xEV-DO system using standard antenna as in 3 sectors per cell;
- Simulate the performance of 1xEV-DO system using “bi-sector” antenna array;
- Simulate the performance of 1xEV-DO system using standard 33º symmetric antenna.
- Investigate the benefit of “bi-sector” solution for 1xEV-DO system by comparing the obtained performance matrix in all three implementations, including
  - Maximum aggregate throughput per sector
  - Average throughput per user
  - Histogram of served data rates

Simulation Approach

- The simulation is done at the system level. The required link-level performance data are obtained from published literature;
- Only the forward link performance is simulated at the first stage;
- Traffics are modeled as fully loaded queues which generate constant traffics;
- Radio channel models are chosen based on ITU standards, including the following effects:
  - Path loss (Modified Hata urban propagation model)
  - Log-normal shadowing with base station correlation factor of 0.5
  - Fast fading is simulated based on Jakes model. The following fading models are simulated:
    - Rayleigh fading with 1, 2 or 3 multi-paths
    - Vehicle speeds varies from 3 to 120 km/h
    - Rician fading with 1.5 Hz Doppler shift

Network Model

- Hexagonal grid with 19 cells is used in cellular topology. Center frequency is 1900 MHz. The following scenarios are simulated:
  - **Reference**: All 19 cells use 3-sector sectorization (standard implementation)
  - **Scattered**: Center cell uses "bi-sector" array, while other cells use standard sectorization
  - **Clustered**: Center cell as well as the first layer neighbor cells use "bi-sector" array, while rest of the cells use standard sectorization
  - **Entire Network**: All 19 cells use "bi-sector" array
  - **Scattered_33**: Center cell uses 6-sector sectorization with standard 33º symmetric antennas, while other cells use 3 –sector sectorization
- BS antenna height = 20 m; Terminal height = 1.5m; Cell radius = 1.7 km.

Fast Fading Models

- Fast fading models are randomly assigned to various users based on assignment probability, which is defined as follows:

Model	Fading Type	Mobile Speed (km/h)	Assignment Probability
A	1 path Rayleigh	3	30%
B	3 path Rayleigh	10	30%
C	2 path Rayleigh	30	20%
D	1 path Rayleigh	120	10%
E	Rician, K= 10 dB	0, f_d = 1.5 Hz	10%

Algorithms Used in the Simulation

Selection of the Best Serving Sector and FL Data Rate

- Choose the sector that has the highest SINR as the best serving sector;
- The SINR of the each user will be compared with pre-defined DRC threshold (obtained from link level performance) to get the highest possible FL data rate;
- The DRC threshold will be adjusted dynamically according channel condition.

Scheduler Algorithm

- A round robin scheduler is implemented at the first stage. All the users have the same chance to be selected for transmission

Algorithms Used in the Simulation

HARQ Algorithm

- Packets are transmitted in slots separated in time (by three other slots used for independent transmission of other packets);
- Each user updates its requested data rate every 4 slots;
- AP will calculate the required number of slots using the updated feedback information of a selected user in the scheduler;
- If a packet is successfully transmitted in fewer slots than the maximum granted number, the AP will terminate transmission in the remaining slots;
- The remaining slots will be used for another new transmission.

Simulation Result # 1
Average Throughput per Sector

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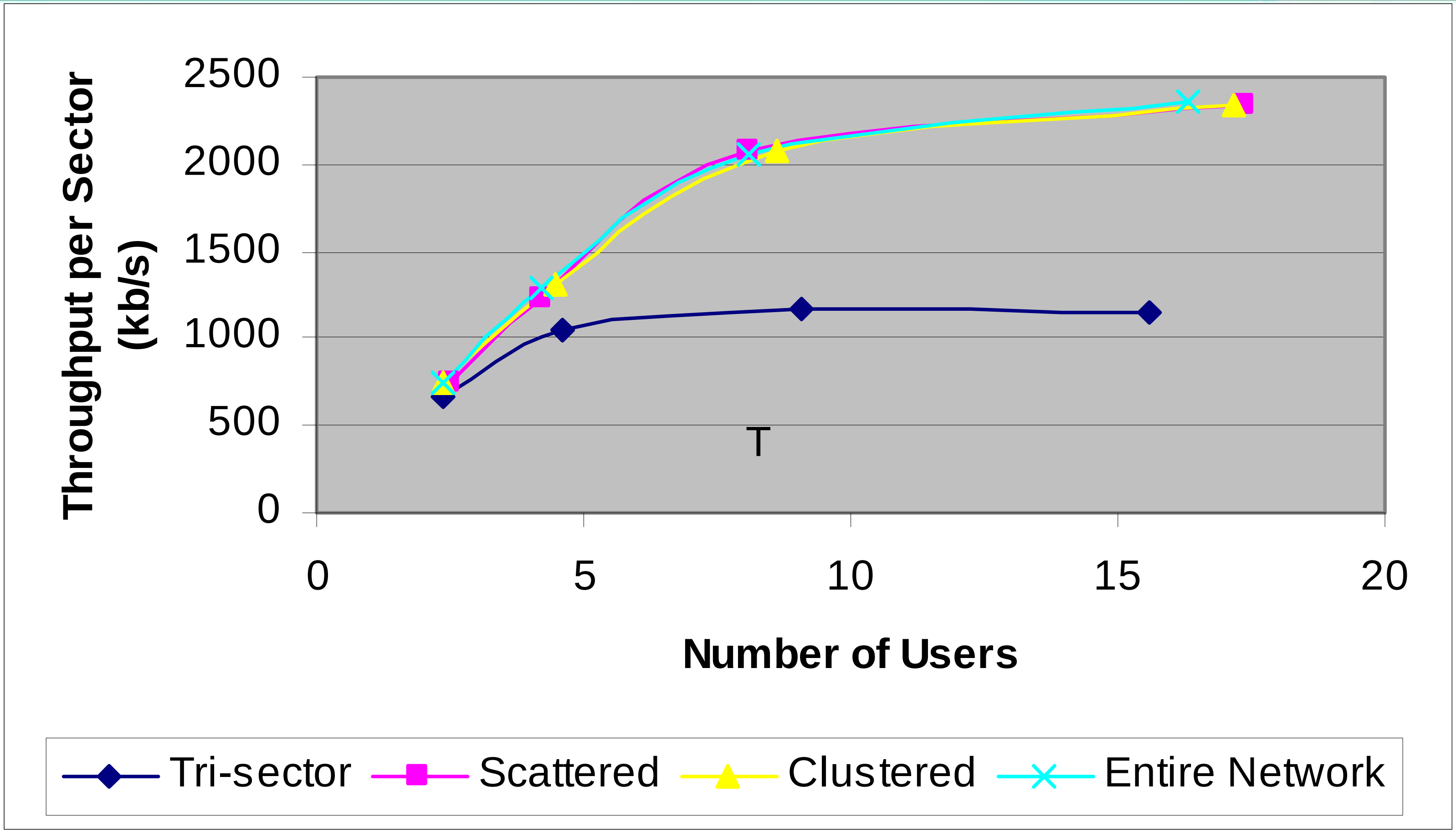
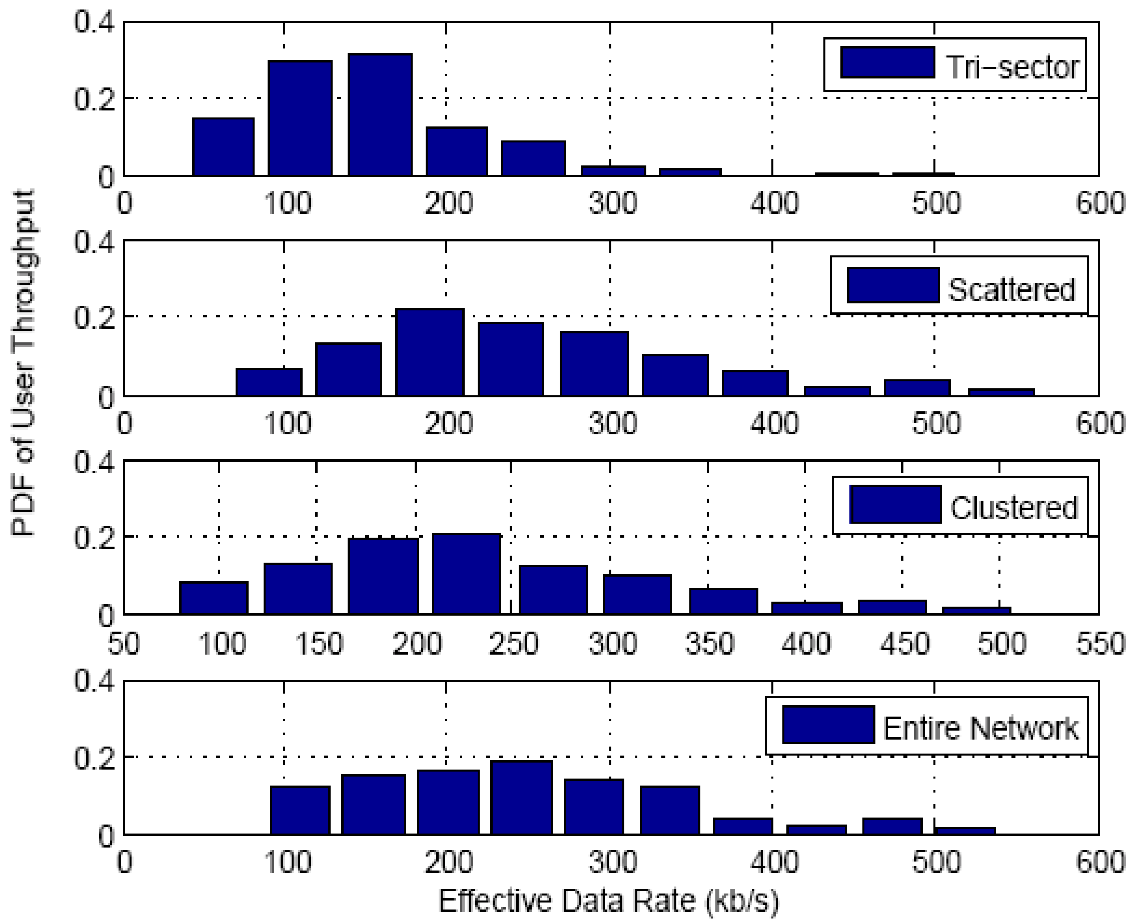


- Max throughput per sector can be increased by 1.8 to 1.9 by using “bi-sector” array;
- Scattered and Clustered deployment of "bi-sector" gave similar performance than "bi-sector" deployment in the entire network. Bi-sector array perfectly address hotspots

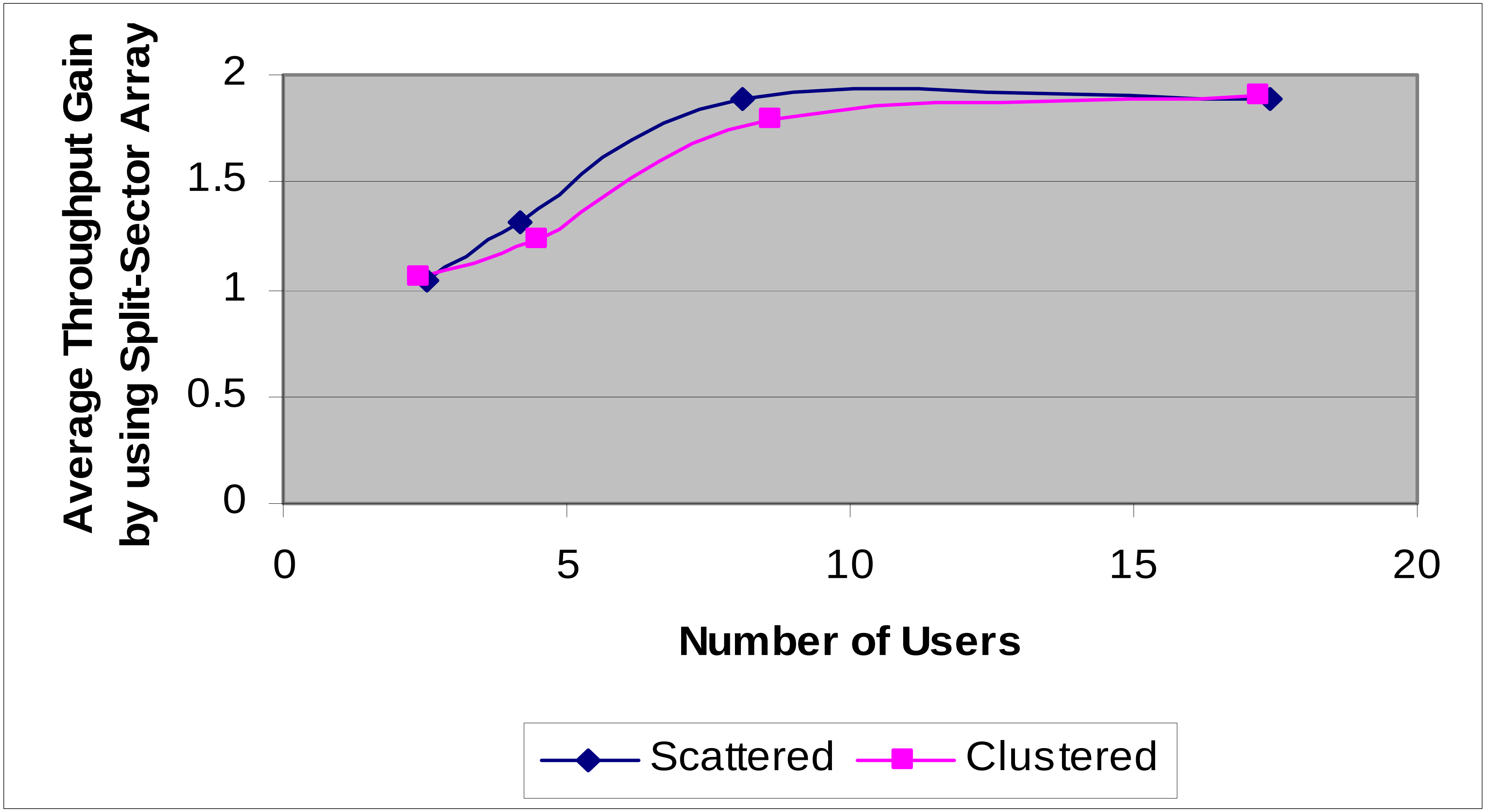
Simulation Result # 2
PDF of User Throughput



Scenario	Ave_Throughput
Tri-sector	141.3 kb/s
Scattered	265.7 kb/s
Clustered	253.1 kb/s
Entire Network	265.6 kb/s

- Compared to the standard 65 degree sector (Tri-sector), the average throughput can be improved by a gain 1.88 by using "bi-sector" array in the center cell (Scattered), provided that there are the same number of served users per section in both scenarios
- Not much further gain is obtained by using "bi-sector" array in clustered or entire network deployment.

Simulation Result # 3
Gain of Using “Bi-sector" Array

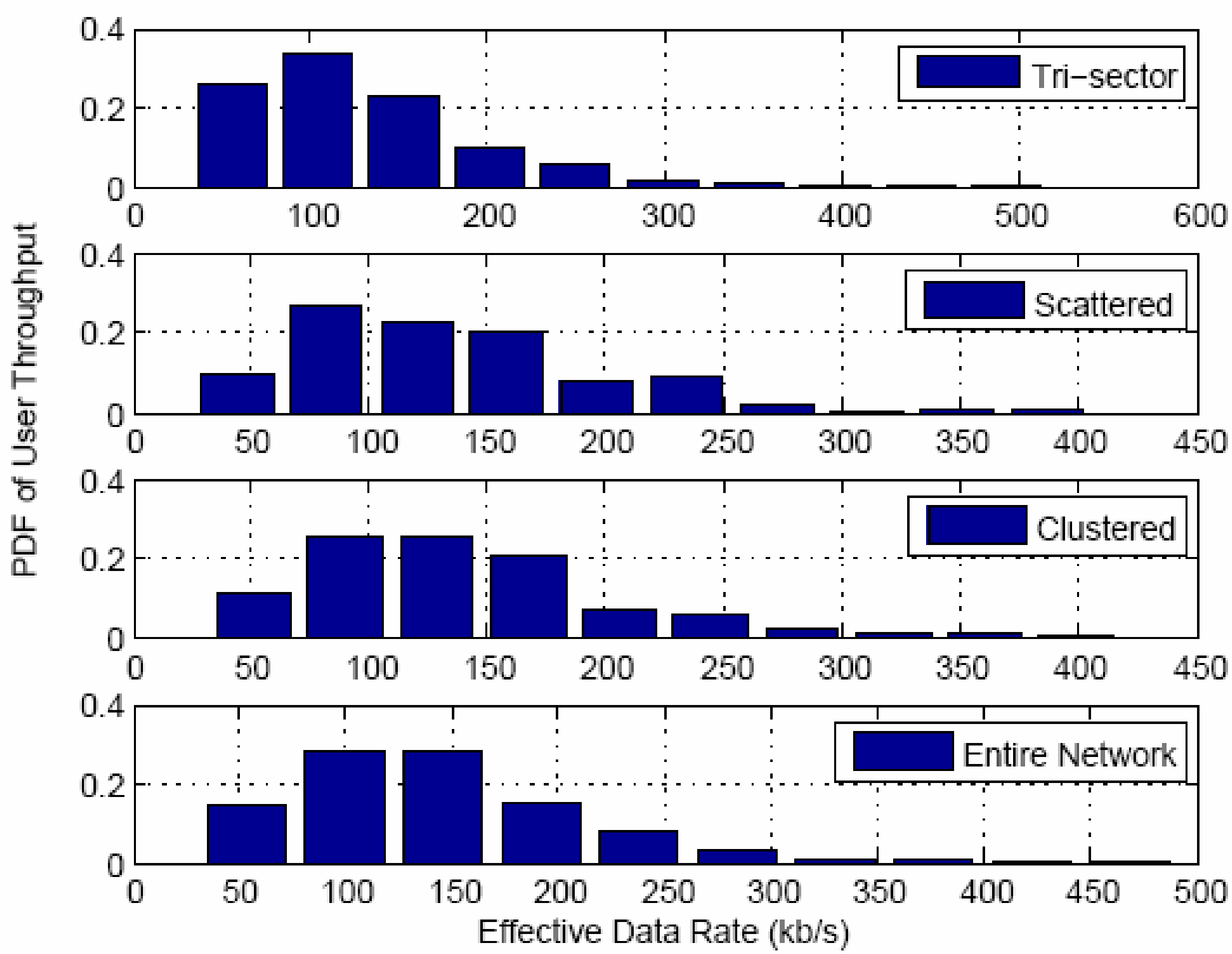


Simulation Result # 4
Average Number of Served Users

- Under the condition of the same average throughput per user, the average number of users can be increased by 1.9 when using "bi-sector" array

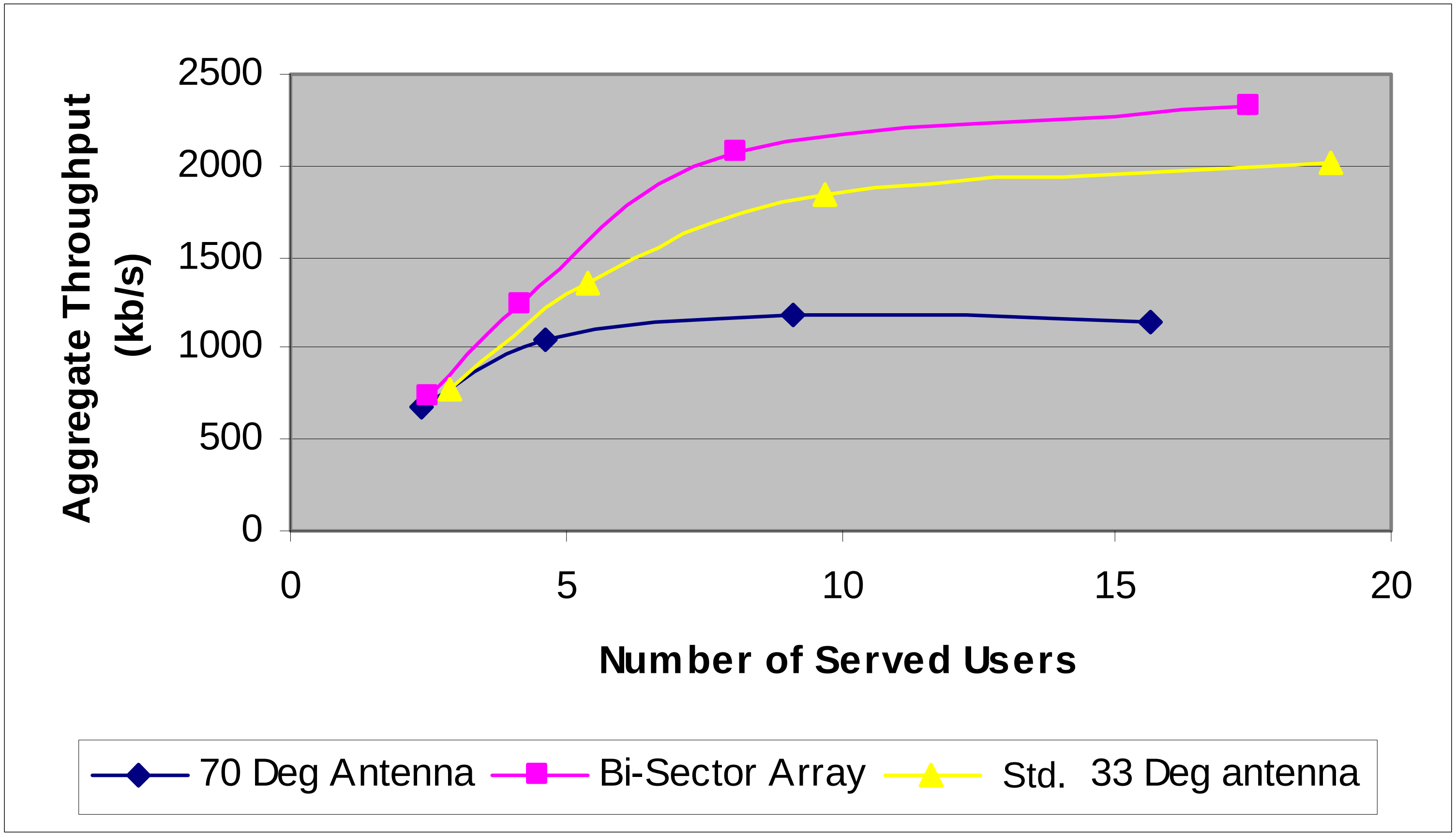
Scenario	Throughput per Sector (kb/s)	Ave Throughput per User (kb/s)	Ave Number of Served User per sector
Tri-sector	1167.2	139.9	9.1
Scattered	2330.4	141.6	17.4
Clustered	2334.6	142.8	17.2

Simulation Result # 5
PDF of User Throughput



- The average user throughput does not increase if the number of served users after deploying the "bi-sector" array increases.

Simulation Result # 6 – Standard 33º Symmetric Antenna versus "Bi-sector" Array



- The maximum aggregate throughput gain when deploying standard 33° antennas is 1.7x
- The achieved throughput by standard 33° antennas is lower than the one achieved with the "bi-sector" array

Simulation Result # 7 – Standard 33º Symmetric Antenna and “Bi-sector" Array

- Unlike "bi-sector" array, standard 33º antenna does not give much improvement concerning the number of served users.

Used Antenna	Agg. Throughput (kb/s)	Ave Throughput per User (kb/s)	Ave Number of Served User
70 Deg Antenna	1179.4	141.3	9.1
“Bi-sector” Array	2330.4	141.6	17.4
2 Standard 33° Antennas	1834.8	206.7	9.7

Conclusion and Application

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Summary

- **"Bi-sector" array is a good solution to increase capacity in hot spots**
  - The gain of using "bi-sector" array increases as the number of served users grows, but reaches the maximum when the number of users per sector is larger than 10;
  - Scattered deployment gave similar benefits as clustered and entire network deployment.
- **Further Investigation**
  - Current scheduler uses round robin algorithm, which ensures fairness at the expense of throughput. Better results should be obtained if proportional fairness algorithm is used;
  - Current traffic model generates constant traffics, which might result in a higher maximum throughput per sector compared to the real situations where users generate HTTP or FTP traffics.

Conclusion

- Capacity gains are available without needing to implement complex solutions at the BTS or chipset level

- Array technology can be used to optimize beamshapes for spectral efficiency gains

- Further investigation of these methods is warranted.