

Switched beam antennas in millimeter-wave band broadband wireless access networks

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Contribution to the proposed new concepts in Session #26

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Switched beam antennas in millimeter-wave band broadband wireless access networks

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OUTLINE

- Motivation
 - OBANET IST-2000-25390 project
- Objectives
- Switched-Beam Antenna scenario
- Performance improvement
 - Interference reduction
 - Multi-path reduction
 - Antenna Gain control
- Protocol adaptation to SBA scenario
- Remarks and conclusion

MOTIVATION

- **Broadband Wireless Access (BWA) Networks**

- High bit rates (>50 Mbps) obly to operate in the millimetre-wave band (targeted band 40-43 GHz)

- Frame duration 1 ms, channel size 28 MHz and M-QAM modulations formats **→** target >50 Mbps

- Natural and artificial conditions drastically impair at mm-wave frequencies: rain, vegetation, man-made obstacles

- **Flexibility and Efficiency → Smart Antennas**

- Dynamic antenna gain and coverage area

- Reduced multi-path and interferences

- Higher spectral efficiency and SDMA

Smart Antennas at 40 GHz?

MOTIVATION

Smart Antennas at 40 GHz

- **Adaptive antennas: DSP and RF/IF**
 - Very high speed DSPs (not yet available)
 - Beam-squint (radiation pattern depends on frequency)
 - High speed switches required for beam-switching.
 - Bulky hardware is required

Proposed approach

- **Switched-Beam Antennas (SBA)**
- Simplified architectures: optical beamforming, Butler matrix
 - however, the proposed strategies are technology-independent
- True-Time Delay is achieved \longrightarrow no beam-squint
- Ultra-fast switching times up to nanoseconds

OBJECTIVES

- **SBA is the simplest smart-antenna technology at 40 GHz suited as first implementation**

OBJECTIVE 1: To demonstrate the benefits of introducing SBA in BWA networks

- **However, BWA protocols must be adapted to introduce SBA → overhead**

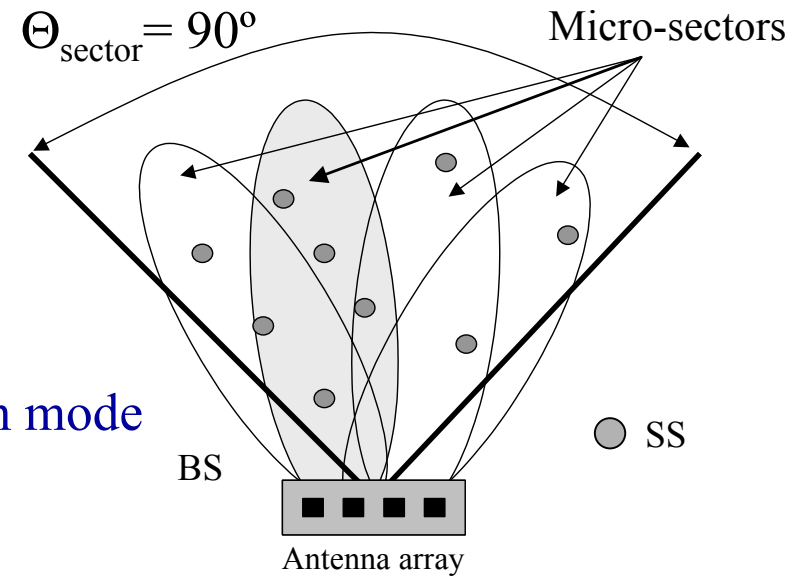
OBJECTIVE 2: To propose a adaptation to introduce SBA scenario in the BWA protocols

OBJECTIVE 3: To introduce an strategy to reduce the overhead

SWITCHED BEAM ANTENNA SCENARIO

- **Scenario defined fitting IEEE/ETSI draft standards (2001)**

- Operation frequency: 42.7 GHz
- IEEE/ETSI fixed frame format
- TDD and TDM/TDMA operation mode



- **SBA control and performance evaluated**

- Interference and multipath reduction
- Antenna gain control
- Adaptation of BWA protocols reducing overhead
- pointing directions and beamwidths

PERFORMANCE OPTIMISATION

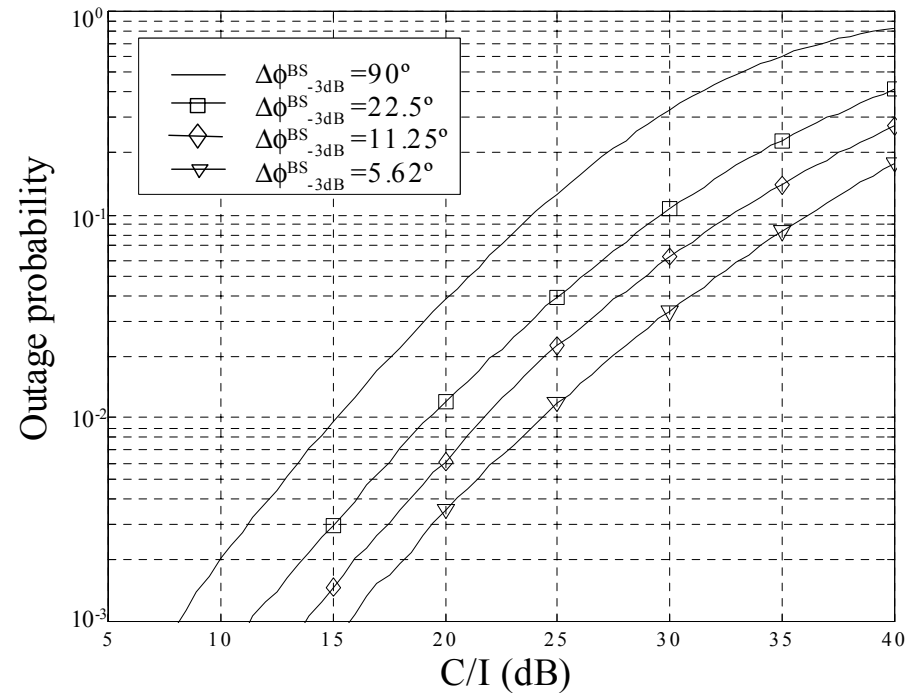
• Interference reduction

— Outage probability as a function of the required C/I for different SBA configurations ($SLL^{BS} = 20$ dB, $SLL^{SS} = 15$ dB and $\Delta\phi^{SS}_{-3dB} = 3^\circ$) in the downlink direction

f2h	f1v	f1v	f2h	f2h	f1v	f1v	f2h
f1h	f2v	f2v	f1h	f1h	f2v	f2v	f1h
f1h	f2v	f2v	f1h	f1h	f2v	f2v	f1h
f2h	f1v	f1v	f2h	f2h	f1v	f1v	f2h
f2h	f1v	f1v	f2h	f2h	f1v	f1v	f2h
f1h	f2v	f2v	f1h	f1h	f2v	f2v	f1h
f1h	f2v	f2v	f1h	f1h	f2v	f2v	f1h
f2h	f1v	f1v	f2h	f2h	f1v	f1v	f2h

Cellular reuse pattern:

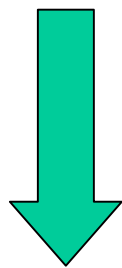
- 2 Frequencies
- 2 Polarisations



PERFORMANCE IMPROVEMENT

- **Interference reduction**

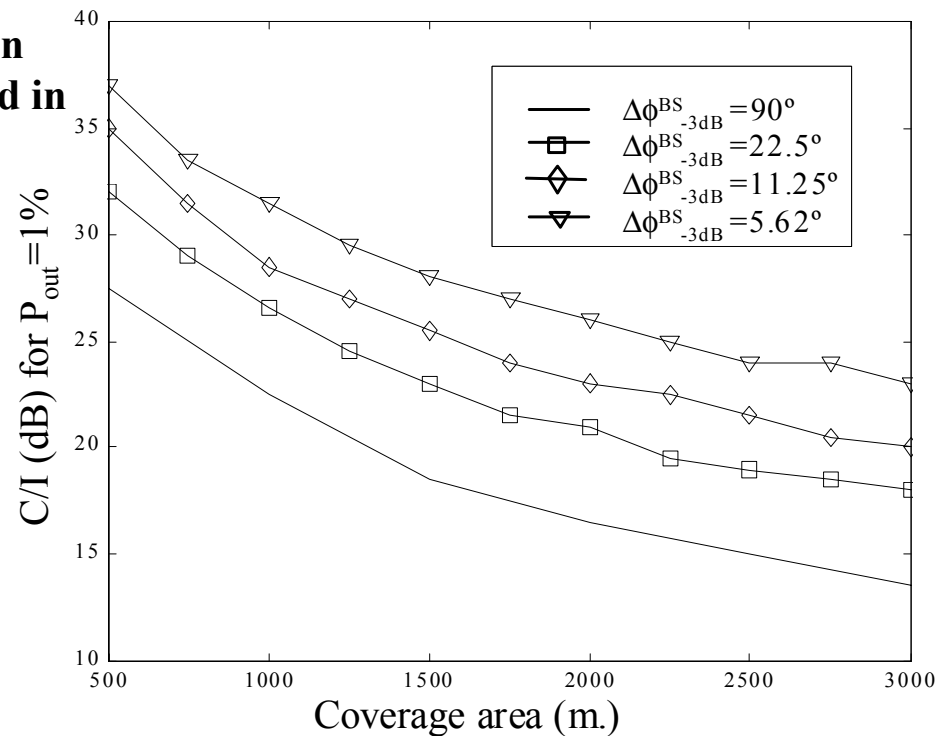
— C/I required to obtain an outage probability of 1% as a function of the radius of the coverage area for different SBA configurations



Higher order modulation formats can be employed in a larger coverage area

$\Delta\phi_{-3dB}$	CA
90°	1200 m
22.5°	2000 m
11.25°	>2500 m

For a BER=10⁻¹¹ at 16-QAM
(required C/I 21 dB)

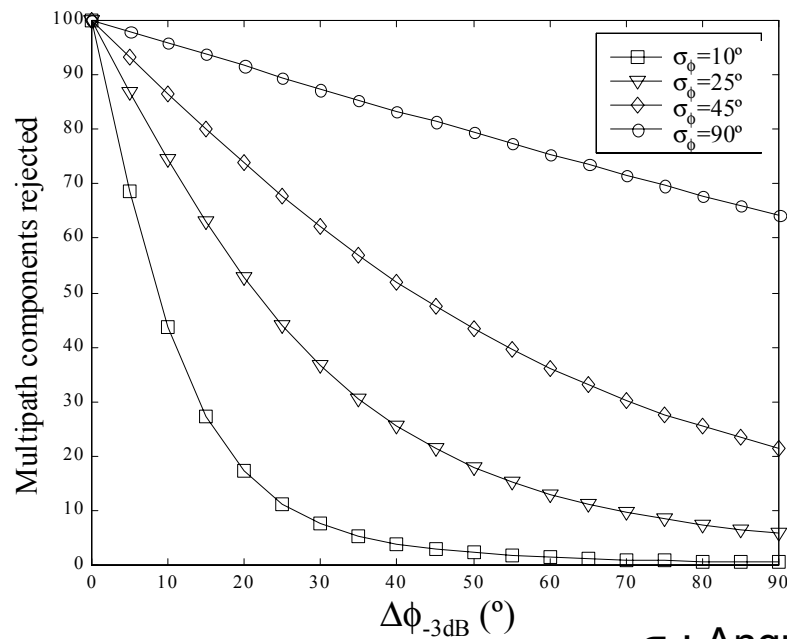


Overall capacity enhancement

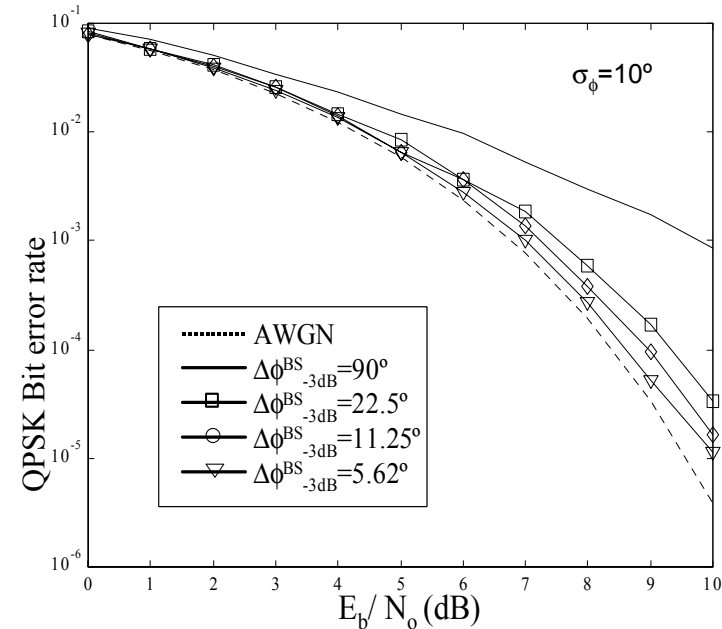
PERFORMANCE IMPROVEMENT

- **Multipath reduction**

- BER improvement
- Temporal dispersion of the channel is reduced
- Easier equalisation → simplified wireless modem design



σ_ϕ : Angular spread



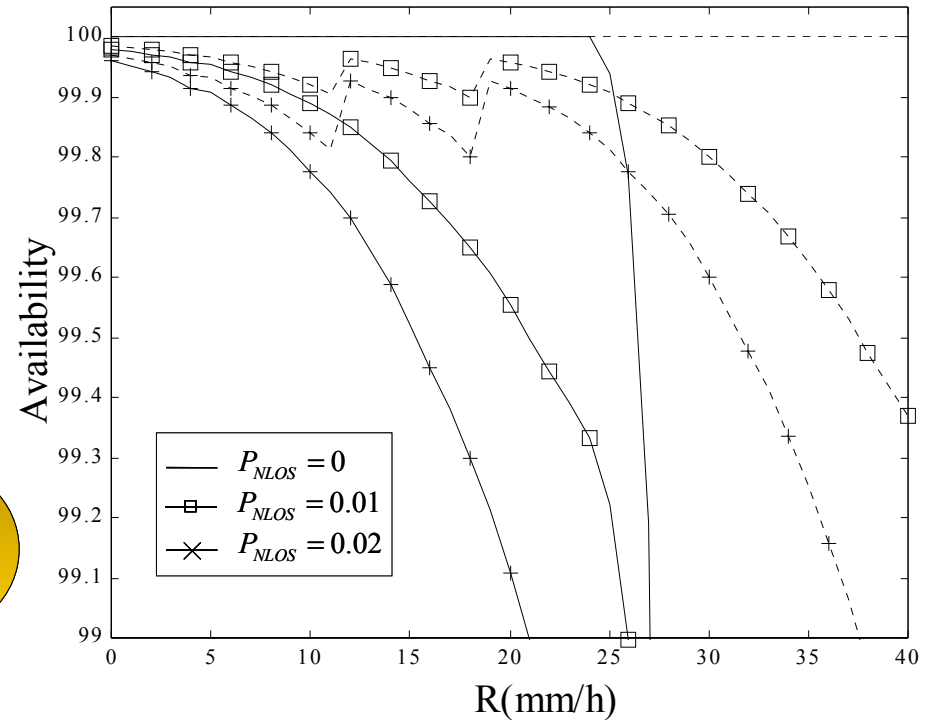
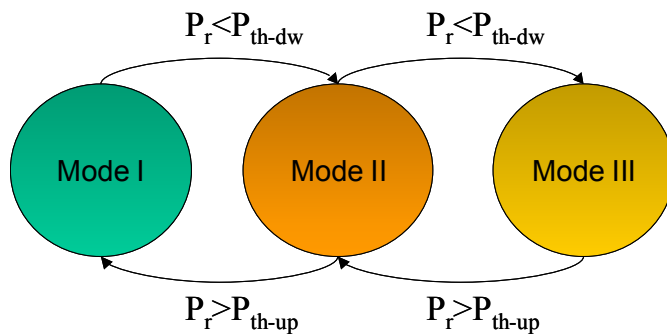
Quality of service improvement

PERFORMANCE IMPROVEMENT

• Dynamic antenna control

- Useful to counteract temporary channel impairments
- Less interferences than Power Control techniques
- Sector reconfiguration possible

MODE	$\Delta\phi_{-3dB}$	ΔG
I	22.5°	0 dB
II	11.25°	3 dB
III	5.65°	6 dB



Availability and Flexibility improvement

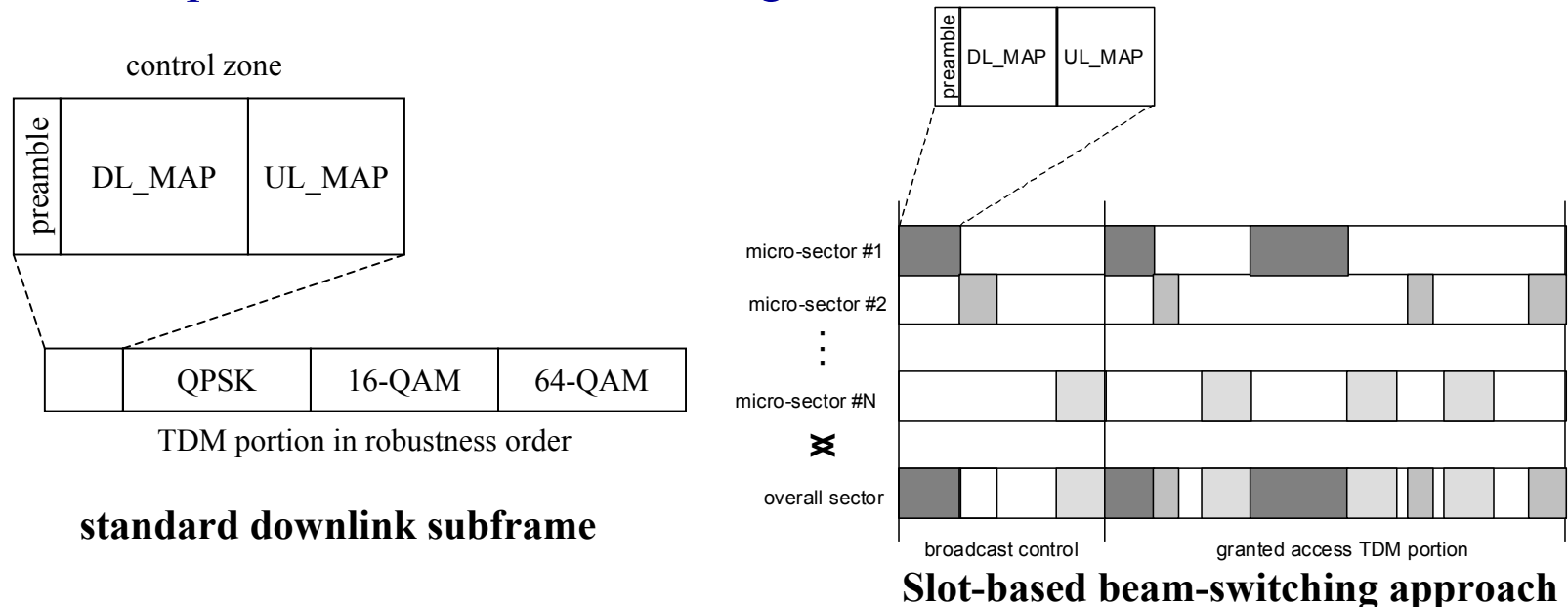
PROTOCOL ADAPTATION

- **Broadcast and contention access**

- Clearly unfeasible in the SBA scenario
- Solution: replication of broadcast and content intervals in each beam
- Introduces overhead, specially the broadcast of control information

- **Adaptation to the SBA scenario**

- Slot-based beam switching approach preferred
- Replication minimization using location



PROTOCOL ADAPTATION

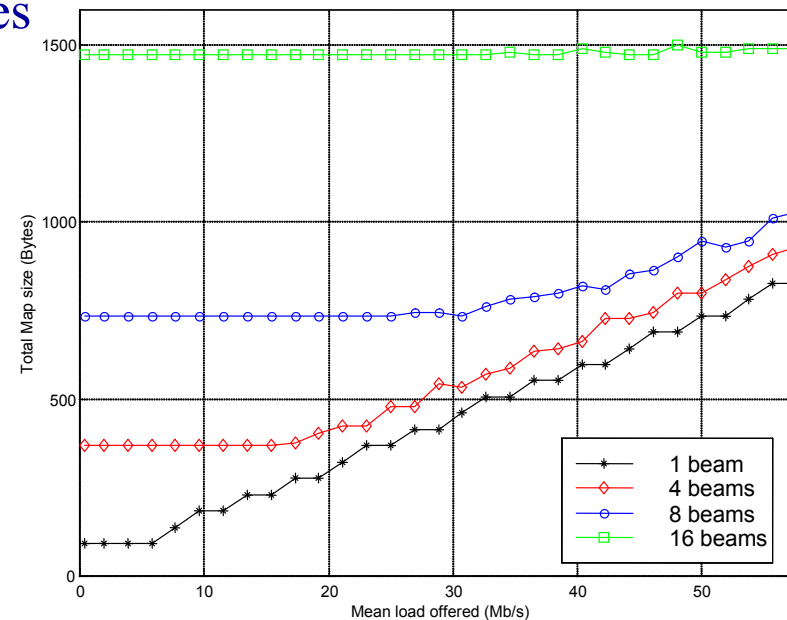
• Map minimisation

- Local DL_MAP and UL_MAP to each beam pointing direction
- Location may be easily obtained in the SS registration
- Only SS present in each beam are mapped in the local DL_MAP
- Only SS present in each beam are allocated in the local UL_MAP
- Different preamble sequences

0		7		8		15	
Frame number				Base Station ID			
Base Station ID				DIUC		Starting	
Symbol		DIUC		Starting Symbol			
DIUC					DIUC	
Starting Symbol				DIUC = 15			

0		7		8		15	
UIUC		Terminal Identification (TID)				Starting Symbol	
Starting Symbol				UIUC=10			
TID=0				Starting Symbol			
UIUC		TID		Starting Symbol			
Starting Symbol				UIUC=10			
TID=0				Starting Symbol			

DL_MAP and UL_MAP format



Low impact for high loads

REMARKS AND CONCLUSION

- **Several strategies making use of beam-forming and fast beam-switching capabilities are possible with adaptive beam-formed BS antennas**
- **The use of such strategies lead mainly to:**
 - interference reduction, capacity improvement
 - better quality of service
 - improved system flexibility
- **These benefits are of key importance for next generation multimedia fixed broadband wireless access networks**

REMARKS AND CONCLUSION

- **A strategy to adapt the SBA scenario and to minimize the protocol overhead introduced in BWA protocols has been proposed:**
 - slot-based beam-switching
 - minimization using location
 - efficient for high-loads

Thanks for your attention
More information at <http://ist-obanet.upv.es>