A Multi-hop, Mesh **B**roadband **F**ixed **W**ireless **A**ccess Network *

By

Aditi Ramdorai , Shinichi Nomato , Yoji Kishi, Satoshi Konishi, Shinobu Nanba, Takeshi Kitahara, Yujin Noishiki and Akira Idoue

KDDI R&D LABS

*This work is supported by KDDI R&D Laboratories Inc. in Japan

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Agenda

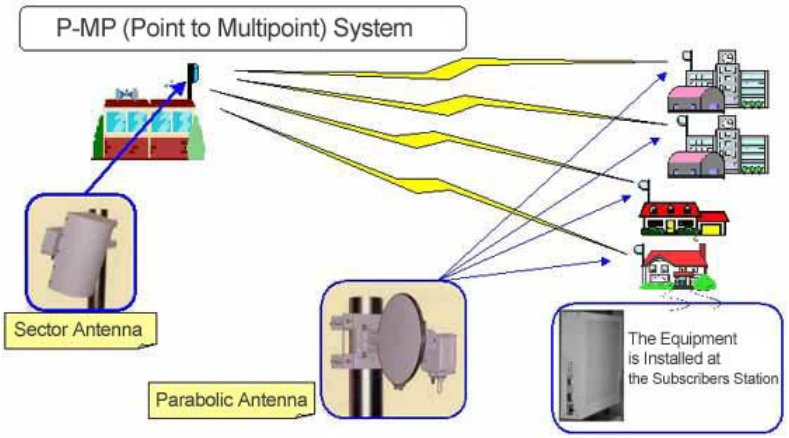
- Introduction to BFWA
- System Characteristics
- Performance Evaluation
- Conclusion

Introduction

- **B**roadband **F**ixed **W**ireless **A**ccess
  - Provide wireless communications using fixed terminals as a „last mile“ solution
  - Operating at millimeter wavelength (>17GHz)
  - Conventional Systems are P-P or P-MP

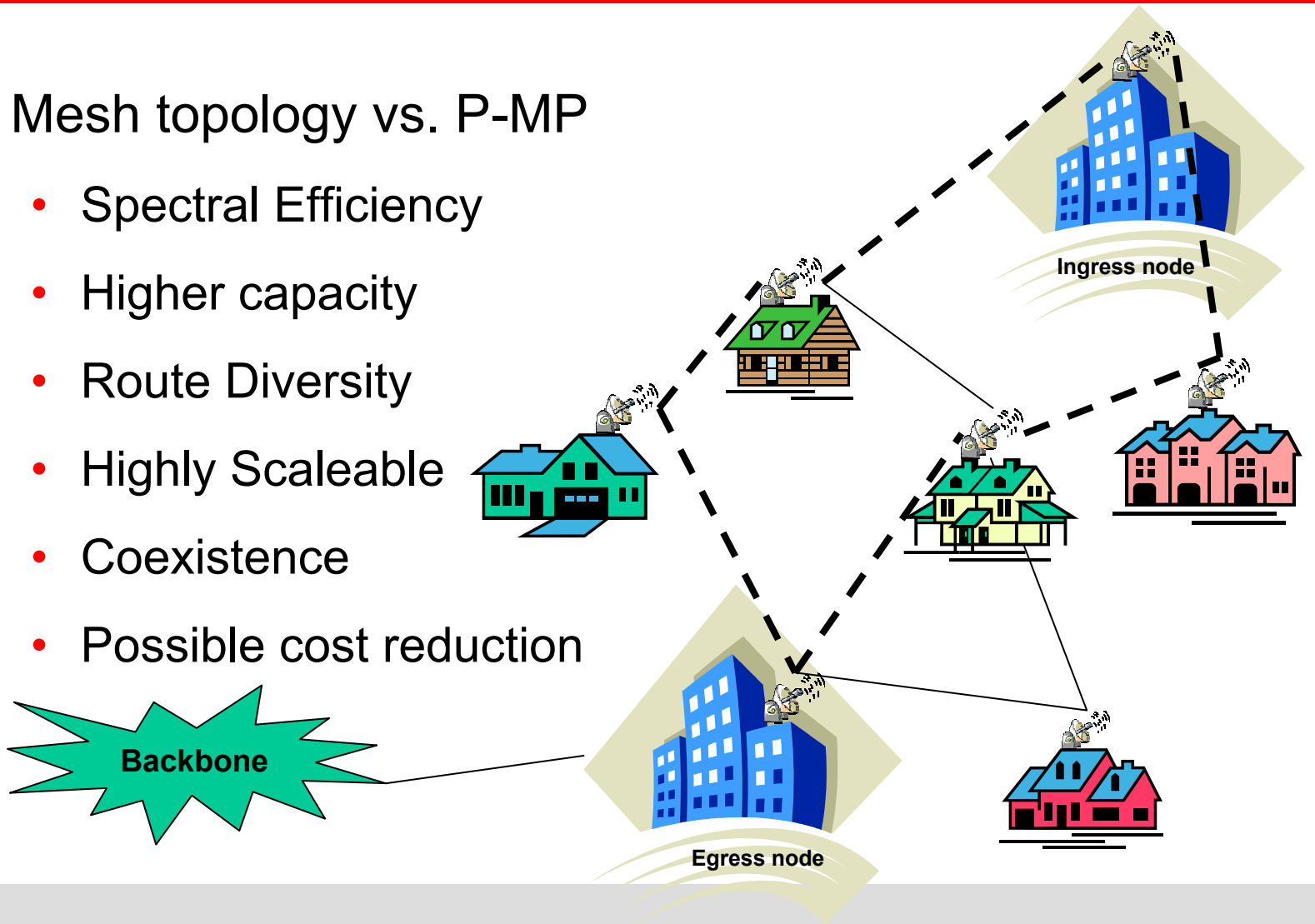
Advantages of BFWA

- High speed
- High capacity
- Large Coverage area
- Easy deployment
- Cost effective
- An alternative to Cable Modem, DSL, Fibre and Broadband Satellite



Mesh networks

- Mesh topology vs. P-MP
  - Spectral Efficiency
  - Higher capacity
  - Route Diversity
  - Highly Scaleable
  - Coexistence
  - Possible cost reduction



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BFWA @ KDDI R&D LABS

- Multi-hop.
- Mesh topology.
- Operating at 26 GHz
- Achieves up to 420Mbps
- MP-MP using a combination of P-P LOS links using directional pencil beam antenna.

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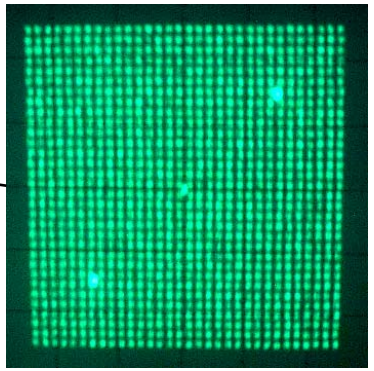
Adaptive System Characteristics

1024QAM Constellation*



Low Spectral Efficiency:

- Solved by Mesh topology and the use of 1024 QAM modems that achieve 7bits/s/Hz

Vulnerability to link quality attenuation due to rainfall :

- Adaptive modulation (QPSK-1024QAM) + route diversity over mesh network

Inflexible towards expansion of network :

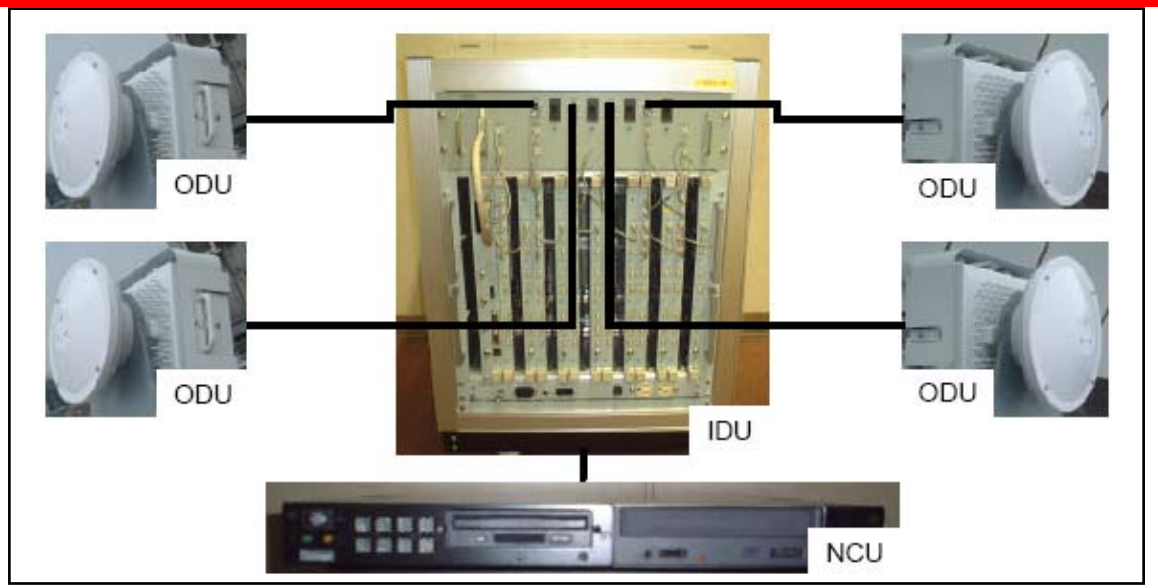
- Decentralized algorithms and dynamic control of frequency slots, routes etc

Low Adaptability for dynamic variation of traffic:

- Adaptive Traffic Load Balancing+ Dynamic TDD boundary control + Dynamic wireless channel allocation

Source: S.Nomoto, et.al "Fully Adaptive MODEM up to 1024QAM for 26GHz Broadband Fixed Wireless Access Systems with Mesh Topology," Proc. of IEEE ISWCS2004

System Characteristics

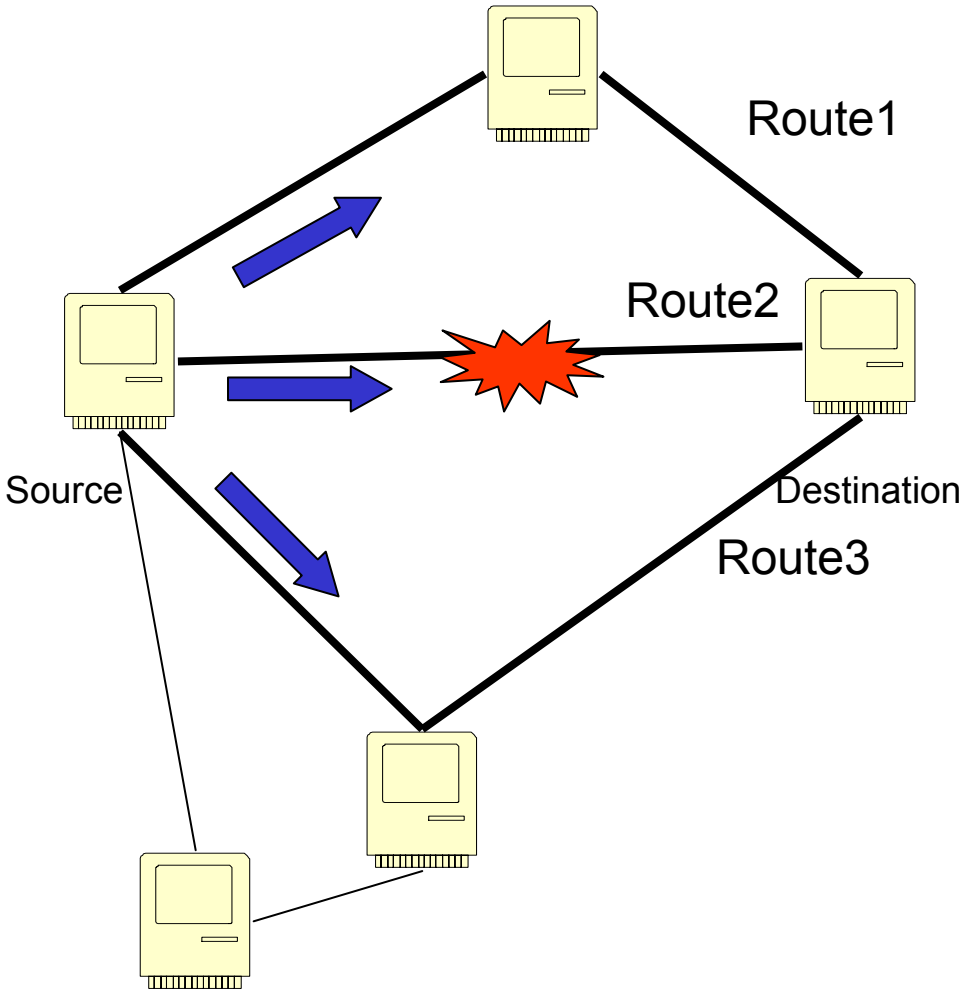


Unit	Major Function
Network Control Unit (NCU)	MPLS routing, channel allocation to links, optimum route selection, load balancing
Outdoor Unit (ODU)	Tx and Rx using directional antennas
Indoor Unit (IDU)	Adaptive modulation and demodulation, dynamic frequency and TDD boundary selection

Source: Y.Kishi et.al, "A proposal of Millimeter-Wave multi-hop Mesh Wireless Network Architecture with Adaptive Network Control Features for Broadband Fixed Wireless Access," Proc. of IEEE RACON2001, pp.17-20

Adaptive load balancing

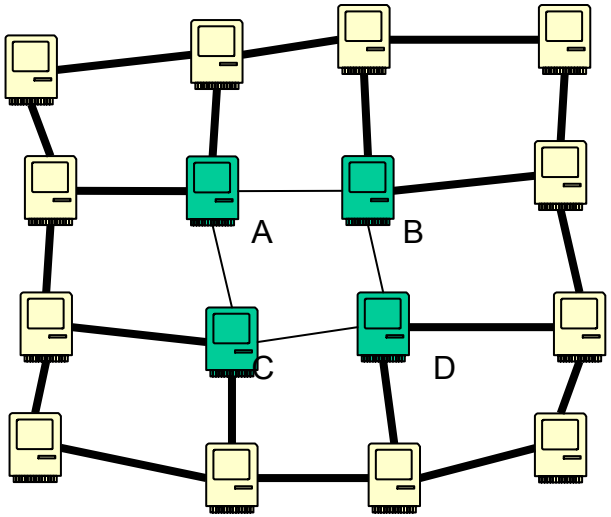
- Causes of link quality degradation could be:
  - Decrease in link quality due to atmospheric conditions
  - Increase of interference/Shadowing
  - Increase of instantaneous traffic along a single route

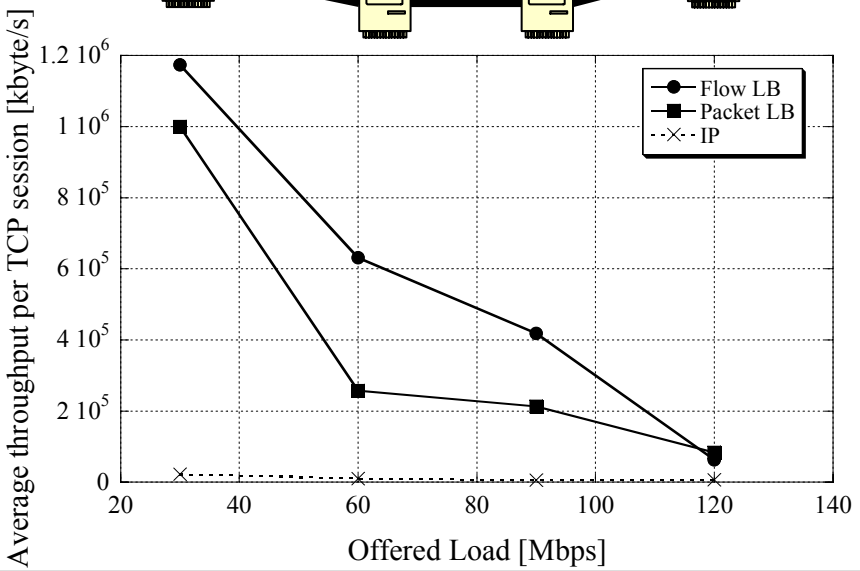


Source: T.Kitahara et.al, "An Adaptive Load Balancing in Multi-hop Mesh Networks for Broadband Fixed Wireless Access Systems,, Proc. of IEEE RAWCON2004 pp.463-pp.466

Advantages over IP routing

- Route diversity
- Higher throughput
- Lower probability of congestion
- Effective utilization of network resources





Source: T.Kitahara et.al, "An Adaptive Load Balancing in Multi-hop Mesh Networks for Broadband Fixed Wireless Access Systems,, Proc. of IEEE RAWCON2004 pp.463-pp.466

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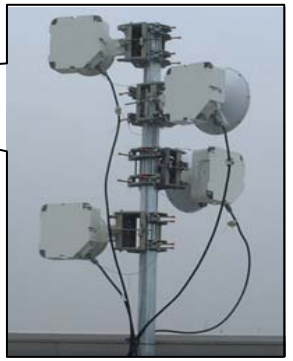
Field Experiment Configuration

A birds eye view



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Wireless Link

( )Distance [m]

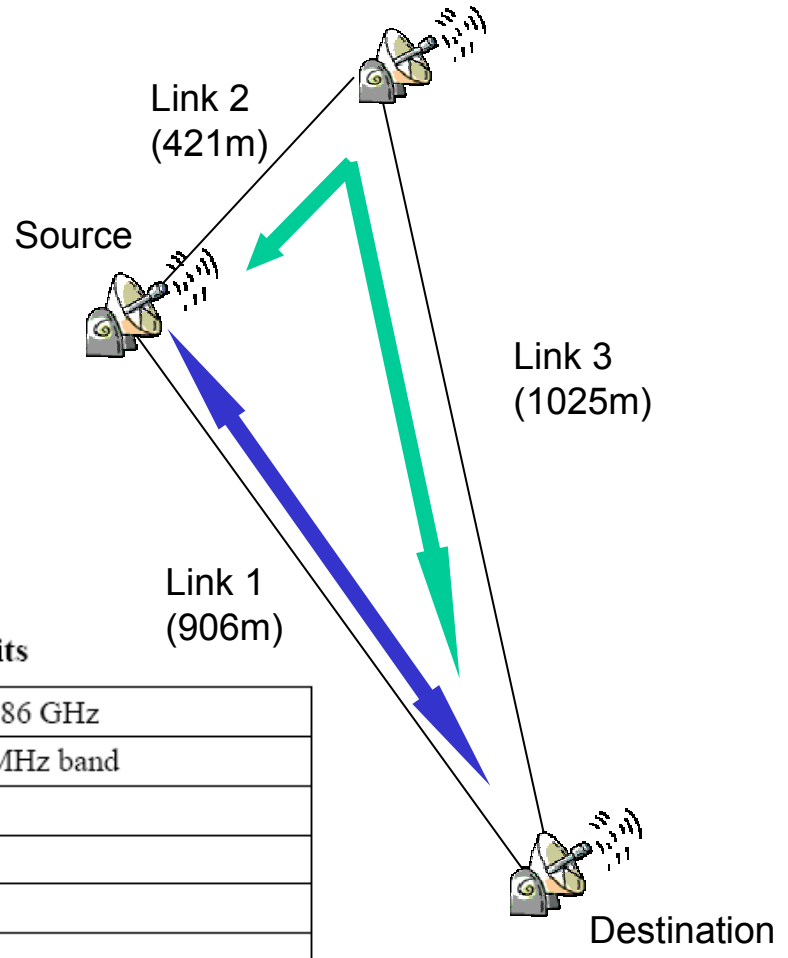
Wireless Node

Performance evaluation

Field Experiment to evaluate Route Diversity:

Link #1 – Direct Route
Link #2 #3 – Diversity Route

Metrics:
- Node availability improvement
- Diversity Gain

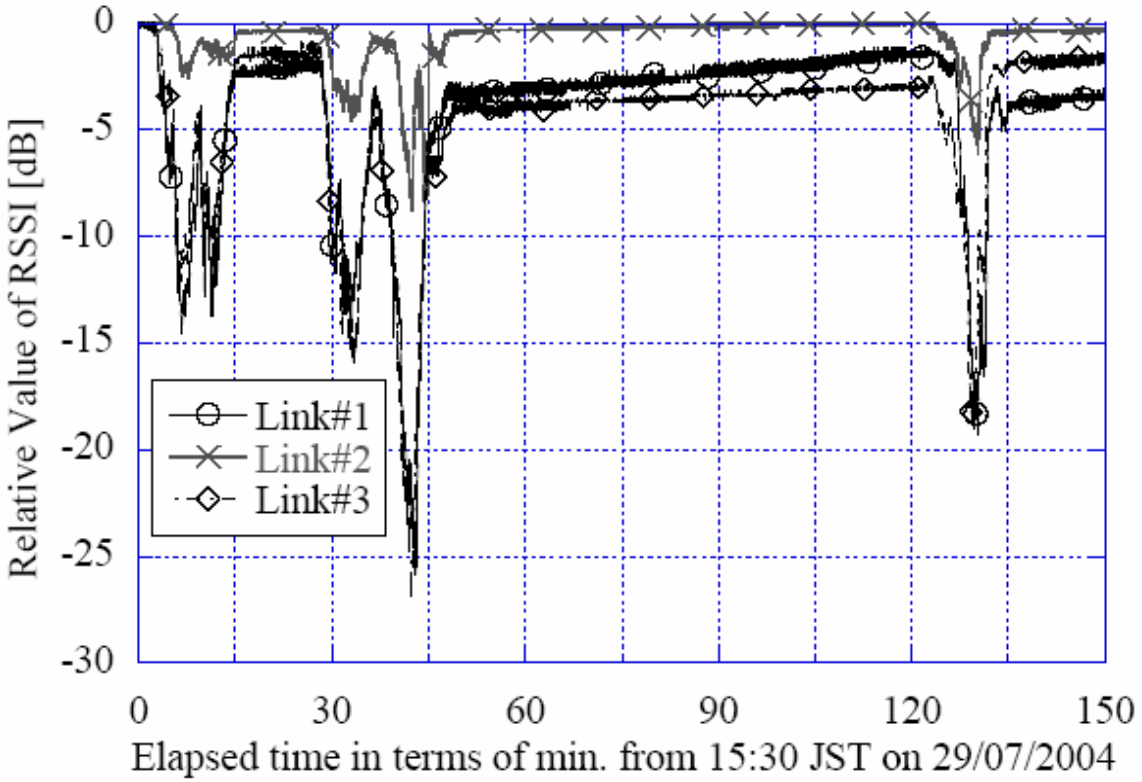


Major specifications of prototype radio units

Radio frequency (RF)	26.80 – 26.86 GHz
Number of frequency slots	7 over 60 MHz band
Frequency slot separation	8.5 MHz
Duplex mode	TDD
Maximum transmission power per carrier	50 mW
Antenna gain	35 dBi

Source: Recommendation ITU-R F.1704 - Characteristics of multipoint-to-multipoint fixed wireless systems with mesh network topology operating in frequency bands above about 17 GHz

Performance Results (on one stormy day...)



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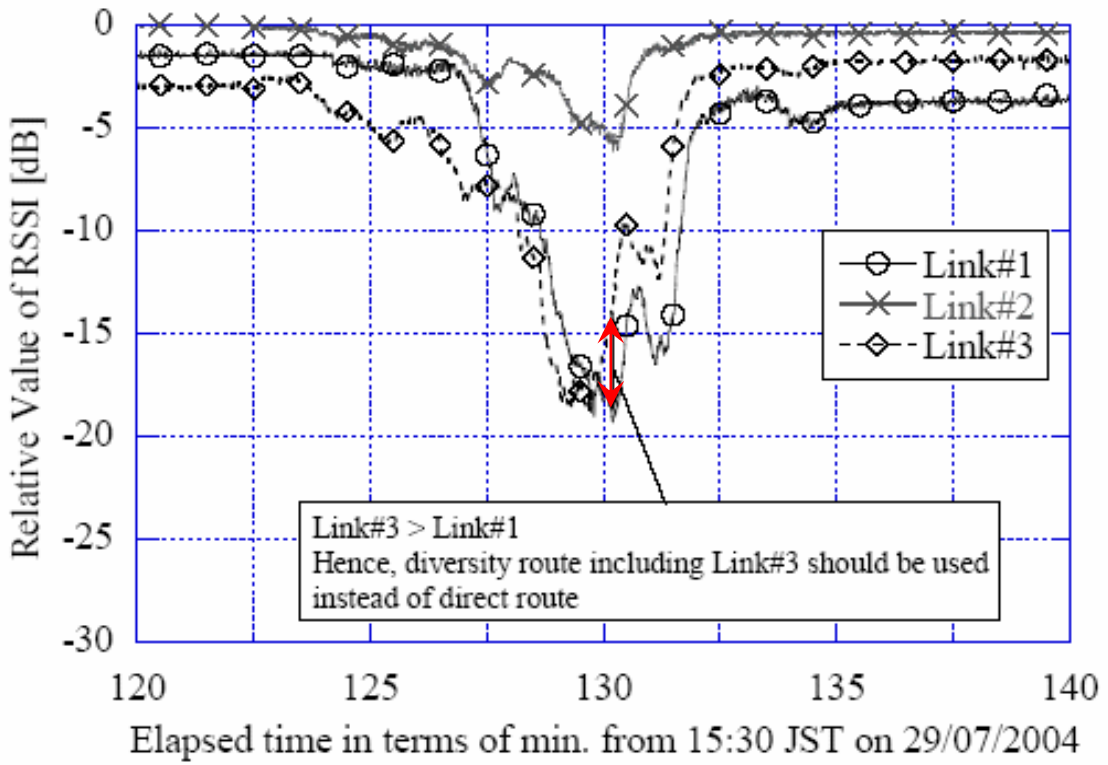
Performance results



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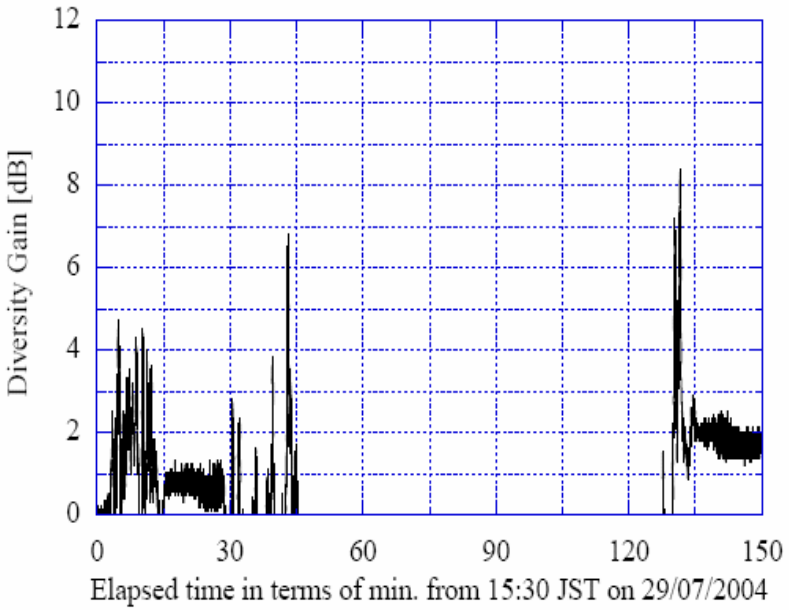
Performance results

- Results:
  - Max. achieved diversity gain more than 8dB
  - At least 1dB gain achieved for 20% of the measurement period
  - At least 3dB gain obtained for 2.4% of measurement period



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Conclusion

- Mesh networks:
  - Route diversity
  - Adaptive techniques
  - Good choice for BFWA!!
- Field experiments show thumbs up.

Thank You

for your attention!!

Contact Information:

Email: aditi@imst.de

Phone: +49-2842-981-464