

## MIMO-MESH: a Self-configurable Wireless Backhaul to Realize Ubiquitous Broadband

Hiroshi Furukawa (furuhiro@picocellular.net)

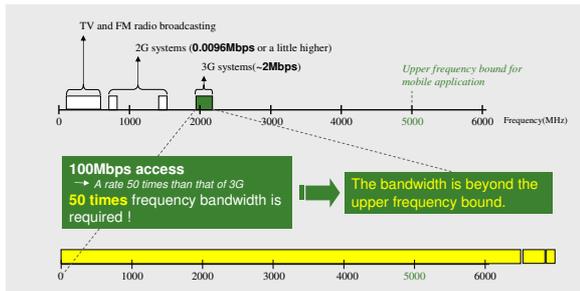
Department of Intelligent Systems  
Kyushu University

## Ubiquitous Broadband

- The recent evolutionary progresses of smart phones raise demands of broadband access anywhere, anytime.
  - Blackberry, Android and iPhone
- Such a ubiquitous broadband access, however, also requires an evolution in their infrastructure.

2

## How much difficulty do we have toward UB society? - Frequency shortage issue



We need an evolutionary solution with 17dB (x50) improvement in capacity

3

## Potential technologies and their capabilities

### Coding scheme

The state-of-the-art coding schemes with iterative decoding, e.g. Turbo, LDPC etc., would be able to offer about a few dB gain compared with legacy convolution coding schemes. The spectrum efficiency improvement is far from the required 17dB improvement.

### Space Division Multiplexing

SDM enabled by MIMO (Multi-Input Multi-Output) has been received much attention for recent decade. However, the 17dB requirement necessitates a number of antennas in both BS and MS, which prevents this scheme from being a great candidate.



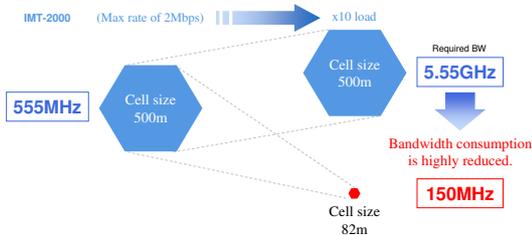
### Small cells

We focus on this traditional approach

4

## Picocell capability: highly bandwidth reduction by densely frequency reuse

We here assume a picocell system with comparable capacity of IMT-2000 while offering increased load being 10 times as much as that assumed for IMT-2000.



However, we need a huge number of cells to cover target zones.

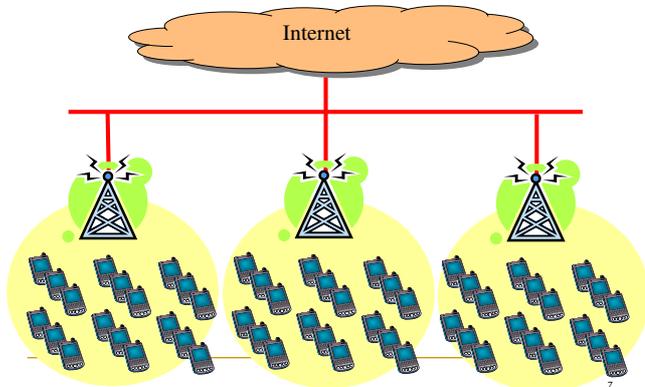
5

## Every cellular system goes to picocell

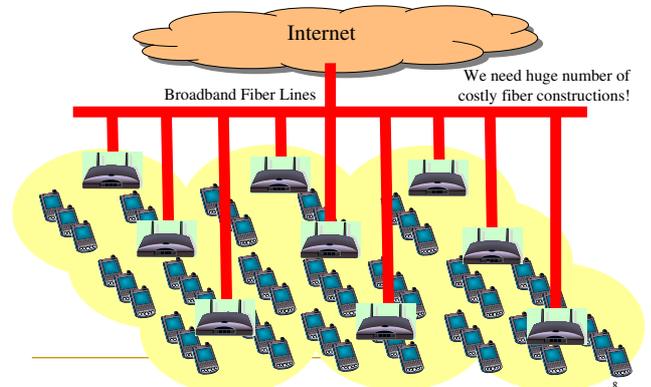
- Every cellular system including WiMAX, HSPA, CDMA2000, etc. goes to picocell.
- e.g. WiMAX
  - [fact] 1.2Mbps on average per user under 20MHz bandwidth and 10 users per cell in 0.5km radius.
    - Reference: Srinivasan et. al., "Downlink Spectral Efficiency of Mobile WiMAX," Proc. IEEE VTC'07 Spring, pp. 2786-2790, April 2007, Dublin
  - **Only 1 user** can have **12Mbps service** in the single 0.5km cell !
  - However, when reducing cell size from 0.5km to 0.16km, then 12Mbps service is possible to all the 10 users dwelling within a 0.5km radius circle in the service area.

6

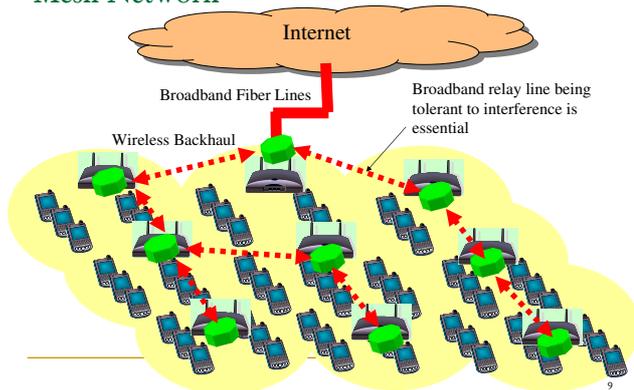
## Cellular System Today



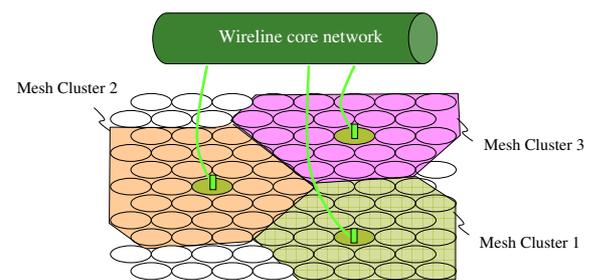
## Ubiquitous Broadband System in Future



## Cost-effective Deployment of Picocells by Mesh Network



## Area Extension by Mesh clusters



Service area can be extended by multiple mesh clusters

## MIMO-MESH project

- A 5-year project supported by Ministry of Education, Culture, Sports, Science and Technology of Japan government
- Objective is to develop high capacity mesh nodes in palm size
- Challenges
  - Multichannel IPT forwarding
  - Battery drive
  - MIMO directional antenna system

11

## MIMO-MESH node



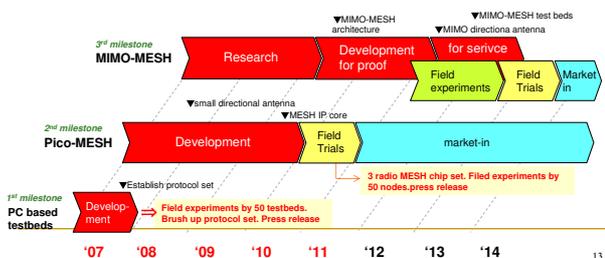
- Original highly efficient packet forwarding protocol (IPT forwarding, L2.5)
- MIMO repeater wireless for high capacity relay lines (in future extension)
- Large scale picocell clustering
- WiFi access capability for Local Wireless
- Ethernet connection
- Easy install and Quick launch without complex configurations. Battery drive

12

## MIMO-MESH project overview

### Objective

- Establish a protocol set to enable large multihop relays in 10 hops or more.
- Develop MESH IP core with low power consumption.
- Establish an MESH-focused MIMO architecture to offer low power consumption and circuit small in size.
- Develop MIMO directional antennas in a few cm square.



## Pico MESH node toward the 1st Milestone



- Automatic route configuration (route formation, route update, etc.)
- IPT forwarding
- Triple Wireless NICs based on IEEE802.11a/b/g
- 900g in weight (inc. batteries)
- 5H battery life by 16x NiMH AA batteries



## Municipal WiFi (Muni-WiFi)

- Public WiFi access networks are introduced into local cities in US to cope with digital divide
- The movement is spreading to other countries outside the US

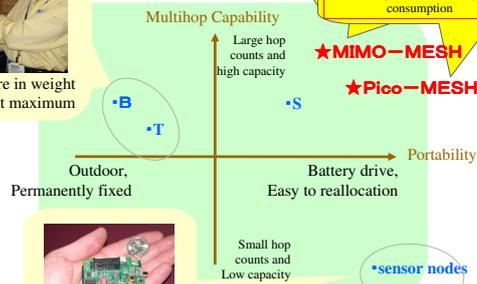


MuniWiFis already deployed or to be deployed in the US

## Our positioning in international competitions



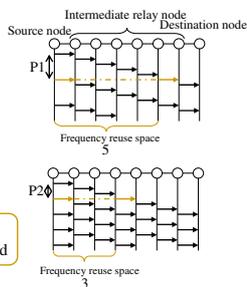
10kg or more in weight  
2~3 hops at maximum



- Technology advantages
- Low power consumption MIMO
  - IPT forwarding
  - Network processor in low power consumption

## Intermittent Periodic Transmit (IPT forwarding)

- IPT forwarding
  - Packets are intermittently transmitted by a source node
  - An intermediate relay node forwards a relaying packet immediately after reception of the packet

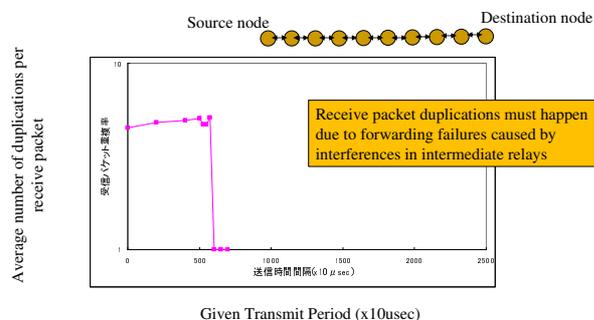


Frequency reuse space attained by the scheme is proportional to the given transmit period

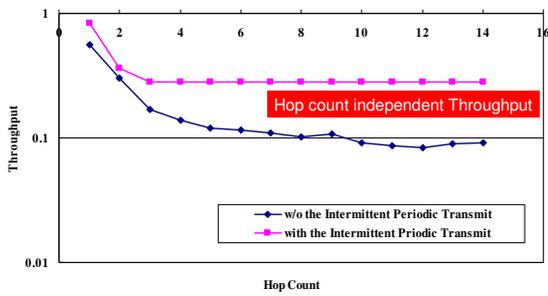
If the transmit period is adequately chosen, interference between adjoining nodes in transmission can be removed

Throughput can be maximized

## Receive packet duplications versus Transmit Period



## Performance of IPT forwarding



19

## Feasibility check by real machines

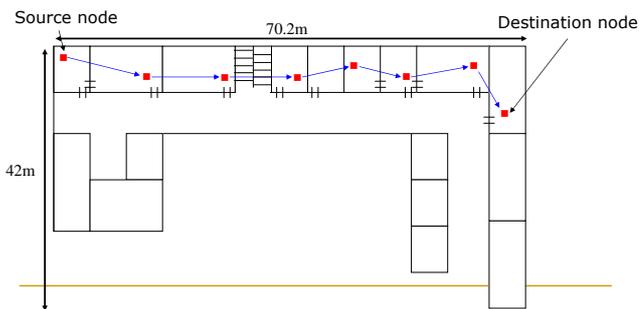


Note PC based mesh node

20

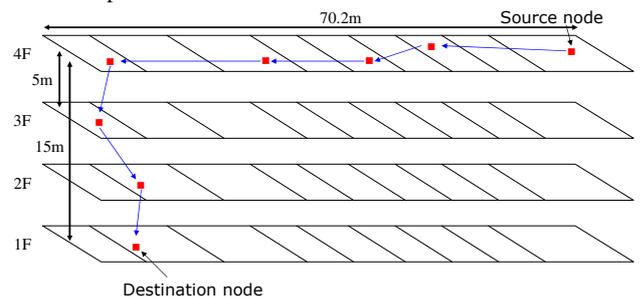
## Node layout – case 1

- 2 dimensional node layout
- 7 hop

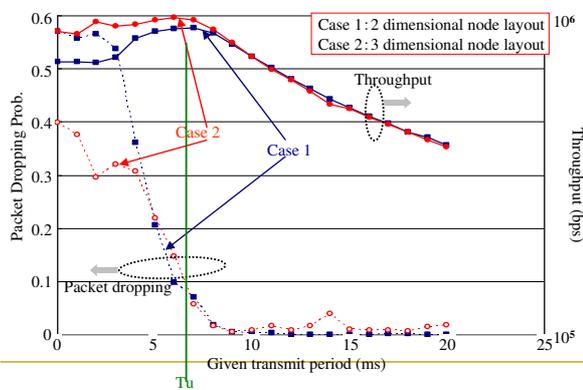


## Node layout – case 2

- 3 dimensional node layout
- 7 hop



## Performance results



## Conclusions

- Every wireless system, even with WiMAX, goes to picocell.
- Mesh network is a key enabler of ubiquitous broadband because it can bring cost-effective backhuls.
- We have launched MIMO-MESH project, a 5 year project supported by Japanese government, to pursue high performance Mesh nodes in palm size.
- Please visit our web site for further information
  - <http://www.picocellular.net>

24