Adaptive Routing Approach and Simulator for IEEE 802.16j WiMAX Mobile Multihop Relay Networks

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Outline

- **Introduction**
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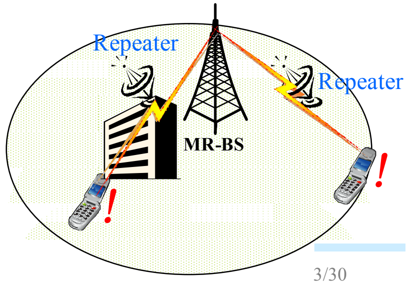
  - Related works
- **Motivations + Goals**
- **Network model**
- **Cost-based Competitive On-Line Routing Algorithm**
- **Numerical Results**
- **Conclusions**

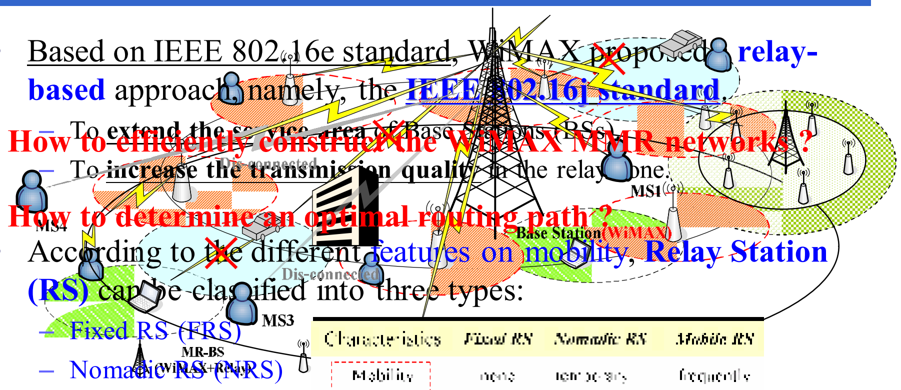
Introduction

- A Wireless Metropolitan Access Network, defined by IEEE 802.16e, has been extensively promoted recently.
  - Support **high mobility** (120 km/hr) and **high data rate** (40 Mb/s).
  - Metropolitan-scale wireless **transmission range** (5km).
- However, signal fading, attenuation, path loss caused by some hiding areas or near cell boundary.
  - **Degrading transmission quality**.
  - Possible solutions:
    - **Deploying more BSs (-)**
    - **Deploying Repeaters (-)**
    - **Deploying Relay stations (v)**



Issue

- Based on IEEE 802.16e standard, WiMAX proposed a **relay-based** approach, namely, the **IEEE 802.16j standard**.
  - To extend the service area of Base Stations (BSs).
  - To increase the transmission quality in the relay zone.
- According to the different features on mobility, **Relay Station (RS)** can be classified into three types:
  - Fixed RS (FRS)
  - Nomadic RS (NRS)
  - Mobile RS (MRS)



Characteristics	Fixed RS	Nomadic RS	Mobile RS
Mobility	none	temporary	frequently
Range	bigger	medium	smaller

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Related works (Three categories)

- ***High-reliability routing*** [3-6] (06-08):
  - **Advantage**- Treat multi-metrics as the evaluation factors.
  - **Disadvantage**- Lack of systematic mechanism for computing optimal weight.
- ***Load-balancing QoS routing*** [7-8] (07):
  - **Advantage**- Considers average bandwidth utilization for multi-hop networks.
  - **Disadvantage**- Can not apply to the IEEE 802.16j Mobile Multi-hop Relay (MMR) networks because of without considering RSs
- ***IEEE 802.16j-based relay routing*** [9-11, 22] (07-09):
  - **Advantage**- The routing path has the highest transmission rate.
  - **Disadvantage**- To use in centralized mode and not meet the nomadic/mobile RSs feature (mobility).

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Motivations + Goals

Motivations

- To propose an IEEE 802.16j-confirmed relay-based adaptive cost-based routing approach that satisfies the IEEE 802.16j specifications.
  - **Fully support for WiMAX MMR networks**
    - Three types of RSs
    - Transmission path length
    - Adaptive Modulation and Coding (AMC)
    - Bandwidth allocation and utilization
  - **To improve the transmission quality by deploying various types of RSs**
  - **To guarantee the path re-routing while RSs moving out of the existing areas**

Goals

- To achieve some goals:
  - **Low blocking rate** and **high utilization** under various impact factors.
  - **Lower end-to-end path delay**.

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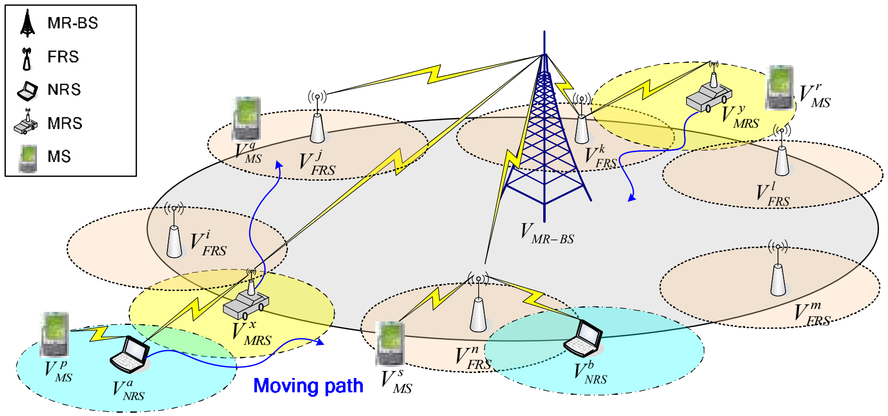
Network model (1/3)



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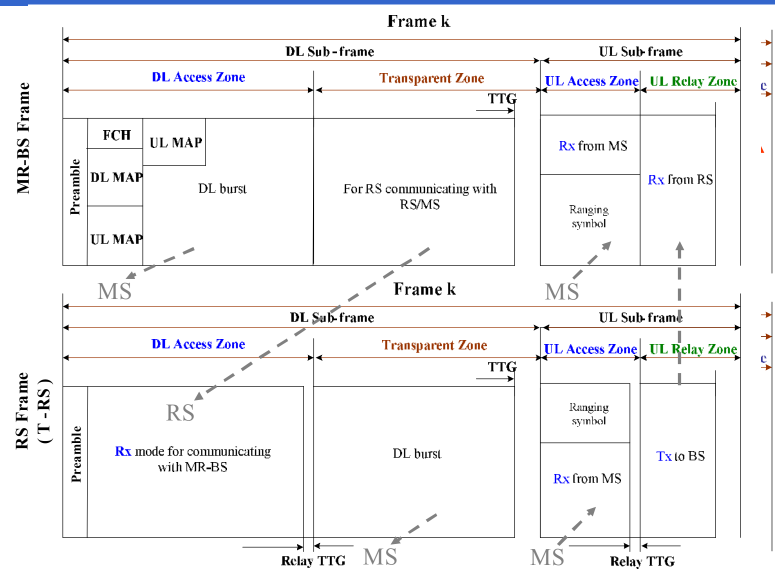
Network model (2/3)



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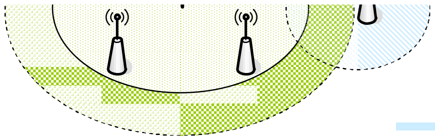
Network model (3/3)

	Transparent mode	*Non-Transparent*
Coverage extension	NO	Yes
Number of hops	2	More
Scheduling	Centralized	Centralized/Distributed
Performance	Improve transmission quality	Improve transmission quality/Outer BS coverage
BS loading	High	Light



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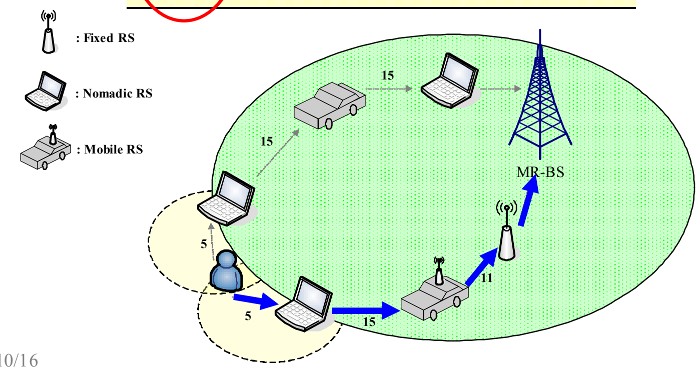
Impact factor 1 - **High Reliability**

Example: In IEEE 80... nd **MRS**, offering di... oving signal attenuation...

Type weight	*MS*	*Fixed RS*	*Nomadic RS*	*Mobile RS*
MS	none	1	5	10
Fixed RS	1	2	6	11
Nomadic RS	5	6	10	15
Mobile RS	10	11	15	20



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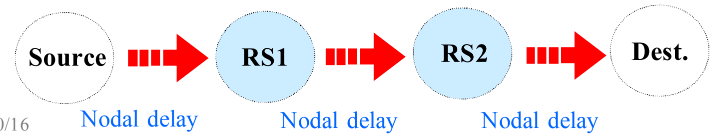
Impact factor 2 - **Low Path Delay**

- The **hop count** of a path significantly affects the end-to-end delay.
  - Less the hop count a path has, less the delay the path yields.
- Normally, a nodal delay time consists of four parts:
  - **Transmission delay**
  - **Propagation delay**
  - **Process delay**
  - **Queuing delay**

Nodal delay time



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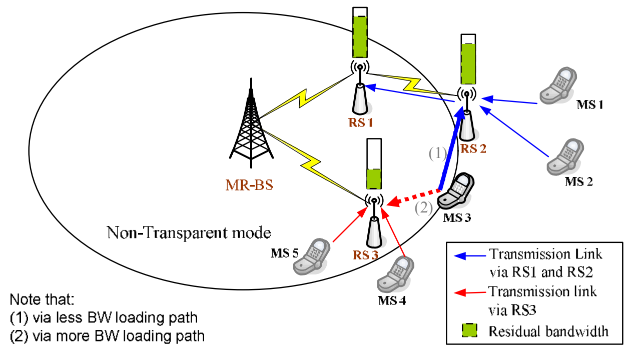
Impact factor 3 - **Load Balancing**

- With limited network resources, the **bandwidth resources** of the MR-BS and RSs can not always satisfy the MS's request.
  - Unbalanced bandwidth utilization
  - --> Higher Blocking & Dropping

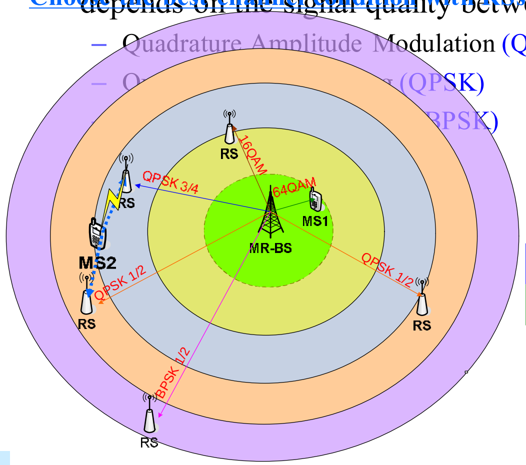


Impact factor 4 - **Different Channel Condition**

Example

Choose the best channel condition with RSs to MR-BS

- In WiMAX, the physical layer's OFDMA coding rate depends on the signal quality between the MR-BS and MS.
  – Quadrature Amplitude Modulation (QAM)
  – Q… (QPSK)
  – …BPSK)



Modulation and inner coding rate	*bit rates (Mb/s)*
64-QAM 2/3	64.91
16-QAM 3/4	48.69
QPSK 3/4	24.34
QPSK 1/2	16.23
BPSK 1/2	8.11

Cost-based Adaptive Routing Path

- Considering the residual bandwidth, path hop-count and AMC channel condition simultaneously.
  – Not required setting different weight values for individual impact factor.
- The proposed cost-based adaptive routing algorithm can be divided into two steps:
  – **A. Cost-based Competitive On-Line Routing**
  – **B. An adaptive Max-Min AMC approach**

If there are several selected routing paths with the same least path cost.

Choose the highest coding rate path.

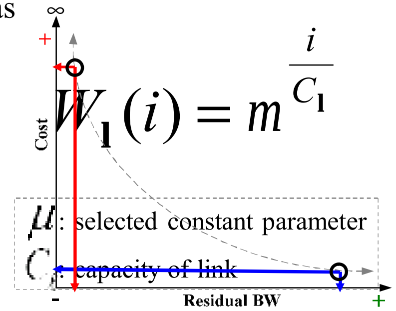
A. Cost-based Competitive On-Line Routing (1/3)

- The COL cost function:
  – The competitive on-line access cost in terms of the **residual bandwidth** of nodes.
- The cost of carrying a call on a node **l** with occupancy *i* can be expressed as

$$W_l(i) = m^{\frac{i}{C_l}}$$

μ: selected constant parameter

C: capacity of link



A. Cost-based Competitive On-Line Routing (2/3)

- Equivalent to setting the admission threshold to one and the cost of a node with occupancy *i* to

$$W_l(i) = m^{\frac{i}{C_l} - 1}$$

$$Since\, 0 \le i \le C_l, we\, have\, 0 \le W_l(i) \le 1$$

To simplify：

A. Cost-based Competitive On-Line Routing (3/3)

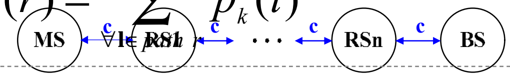
- The **link cost** for <u>class k call</u>, $P_k^l(i)$, are defined herein by

$$p_k^l(i) = \begin{cases} \sum_{j=i}^{i+b_k-1} \mu^{c_l^j} & if \quad i+b_k \le C_l, \\ \infty & otherwise. \end{cases}$$

b_k : the required bandwidth of class k.

- The ***path cost*** is defined by

$$\Gamma_k(r) = \sum_{\forall l \in r} p_k^l(i)$$

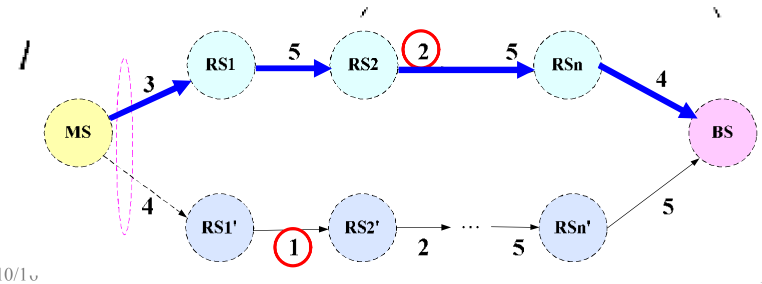


$\Gamma_k(r)$: the cost of carrying a class k call on a multi-hop path r.

B. An adaptive Max-Min AMC approach

- To satisfy the AMC coding rate in MMR networks:

OFDMA Zone Level (from the nearest to the farthest)	Adaptive modulation and coding rate	AMC Index (AMI)
1	64QAM	5
2	16QAM	4
3	QPSK3/4	3
4	QPSK1/2	2
5	BPSK	1



Three important performance metrics

- Fractional Reward Loss (FRL):

$$FRL = \frac{\sum_{k=1}^{K} RW_k \, l_k B_k}{\sum_{k=1}^{K} RW_k \, l_k}$$

k : the service class with the different priority.
l_k: the arrival rate of k class services flow.
RW_k: the reward of class k service flow.
B_k: the blocking rate of class k service flow.

- Average bandwidth utilization (UT):

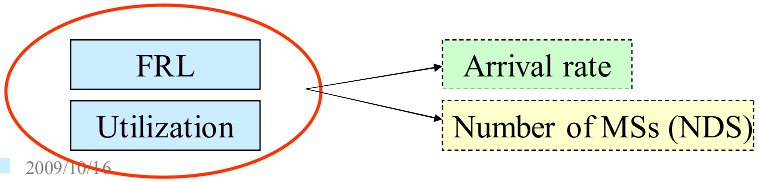
$$Utilization = \frac{Allocated\_BW(W)}{MR - BS_{CAP_w}}$$

- Average path delay time:

$$\sum_{i=1}^{I} d_{nodal_i} = \sum \left(d_{process} + d_{queue} + d_{transmission} + d_{propagation} \right)_i$$

Numerical Results

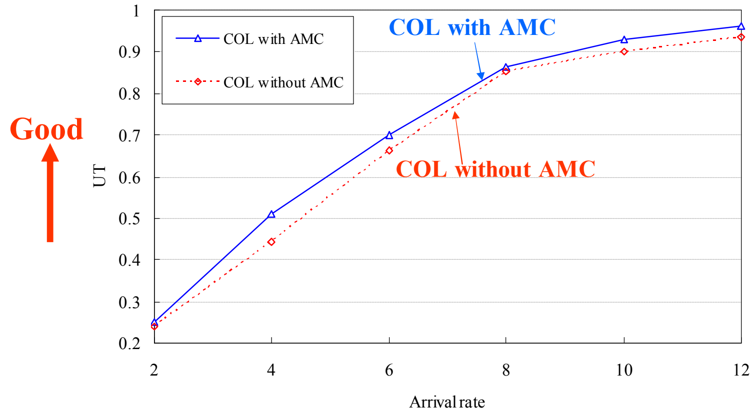
- Several <u>compared approaches</u> for multi-hop relay networks.
  - ***Hop Count (HOP)***
    - To select the shortest path
  - ***RS Type (TYPE)***
    - To select higher reliability routing path
  - ***Bandwidth (BW)***
    - To select higher bandwidth resource routing path
  - ***Normalize dynamic weighting approach (NDWA)***
    - To include multi-metrics and adjust specific weight dynamically.



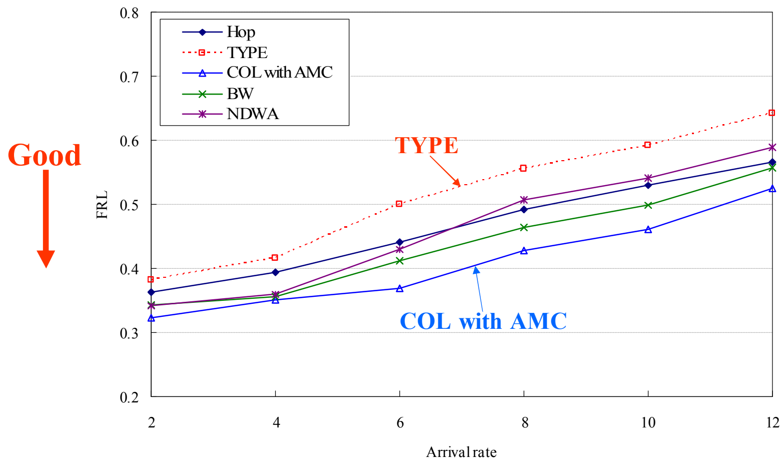
Simulations parameters

	Simulation parameters	Values
Network model	Number of MSs (NDS)	10~70
	Network Size	2000 m
	BS bandwidth	35 Mbps
Traffic model	Bandwidth for UGS (CBR)	64 Kbps
	Bandwidth for rtPS	16 Kbps
	Bandwidth for nrtPS	6 Kbps
	packet size	1200 bytes
	Arrival rate of Poisson distribution, λ (rtPS)	2~12
	Average holding time of Exponential distribution, μ (rtps)	1
	Parameters of Pareto distribution, α on, α off and β (nrtps)	1 1.5 1.1
	Simulation Time	1100 s

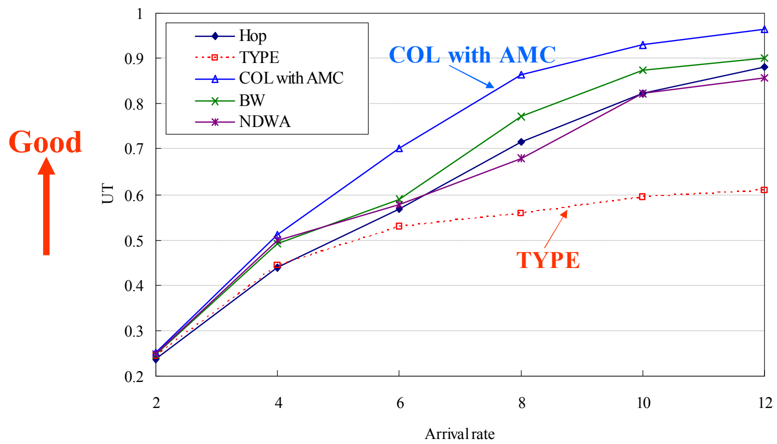
Different MR-BS utilizations in OFDMA system under various arrival rates



FRLs under various arrival rates



Utilization under various arrival rates



FRLs under various numbers of NDS

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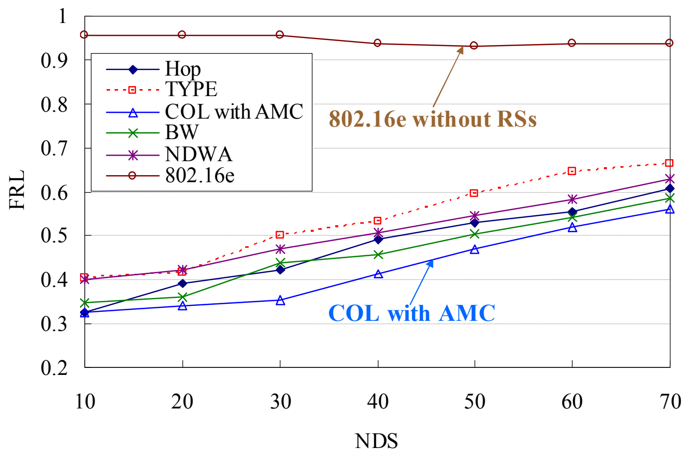

Average end-to-end path delay time under various number of NRSs/MRSs

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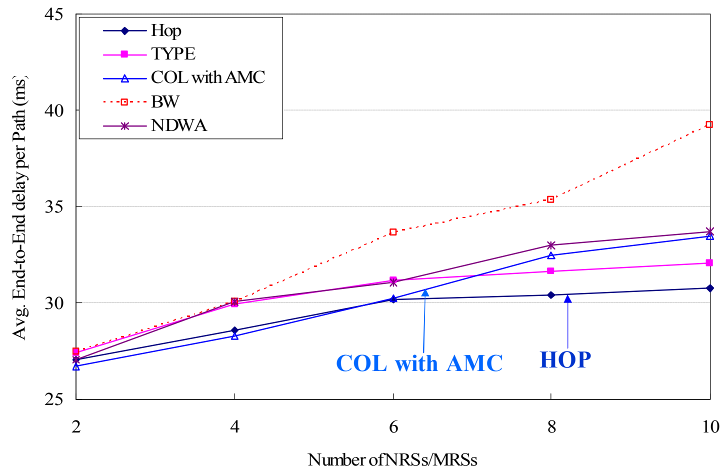

Utilization under various NDS

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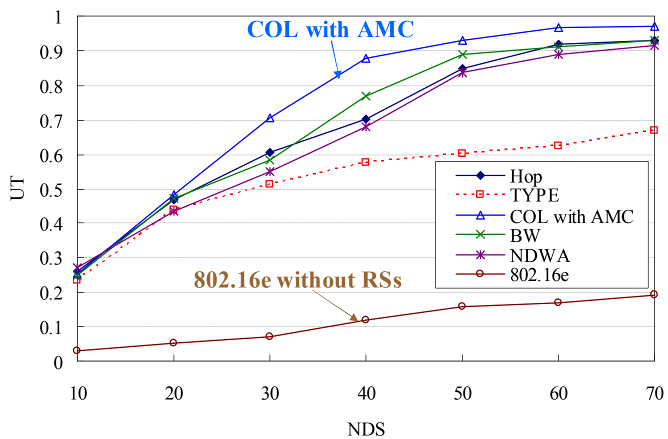
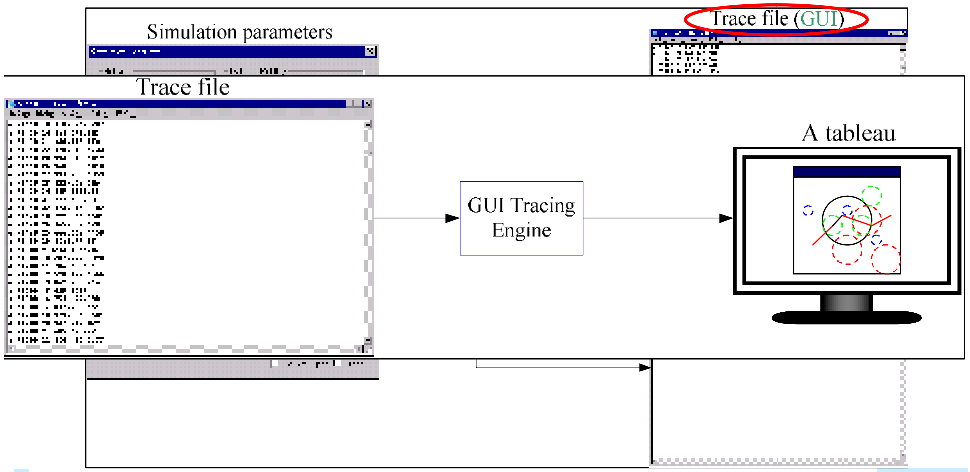


To assist the Numerical Results

- To show MS-RS-BS transmission procedure with **GUI**



Conclusions

- By the hint of determine an optimal routing algorithm in MMR networks, we proposed an adaptive path determination for IEEE 802.16j MMR networks in the *non-transparent mode* with the *distributed* scheme.
  - To improve the MR-BS utilization enhancement.
  - To reduce End-to-end path delay of WiMAX MMR networks.
- The **adaptive COL cost-based approach** with AMC scheme consider the *residual bandwidth*, *path hop count*, *load balancing* and *AMC coding rate*, the determined optimal routing path to achieve:
  - Highly Reliable
  - Data Transmission Rate
  - Satisfying Real-time Streaming Transmission

Q&A

Thank You !