Mobile TV and 3G Multicast

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Oct 30, 2007

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Mobile TV

Mobile phones today have integrated a large number of features

- Camera, camcorder, game console, GPS, music/video player, PDA, …

Mobile TV integration is happening now

- Helps complete the “mobile triple play” of mobile phone, internet and TV services

Three possible delivery mechanisms

- Unicast downloads
- 3G Multicast/Broadcast
  - BCMCS – Broadcast and Multicast Services in CDMA2000
  - MBMS – Multimedia Broadcast Multicast Services in UMTS
- Mobile TV networks for broadcasts
  - DVB-H, DVB-SH
  - MediaFLO (Qualcomm)

Multimedia Content Delivery Methods

Download-and-Play

- Content sent and stored on the end-user terminal
- User needs to wait for download to complete before viewing content
- Used for **non real-time** content

Progressive Download

- A percentage of the download is completed and then the end-user is able to start viewing the content whilst the rest is being downloaded
- Use as a compromise for streamed data in networks with few QoS controls and limited bandwidth and data rates
- Can be used for **real-time** services

Streaming

- Content is streamed to the handset but never actually stored there
- Users have to be in a situation in which they can readily view the content
- Most compelling delivery for **real-time** services

3G Multicast is more efficient than unicast when 3 or more users are downloading/streaming the same content at the same time

Today's Mobile TV

Verizon's VCAST service

- Streaming Video: unicast, 15 frames per second short clips
- Mobile TV: 30 frames per second, 8 Channels

Sprint's MobiTV service

- 13 channels using CDMA2000 packet data
- Downloading of short clips

"3"

- 2 channels, "Big Brother" service from Ericsson using UMTS (circuit data)

Also, KDDI, SK Telecom etc.

Standards/Networks for Mobile TV

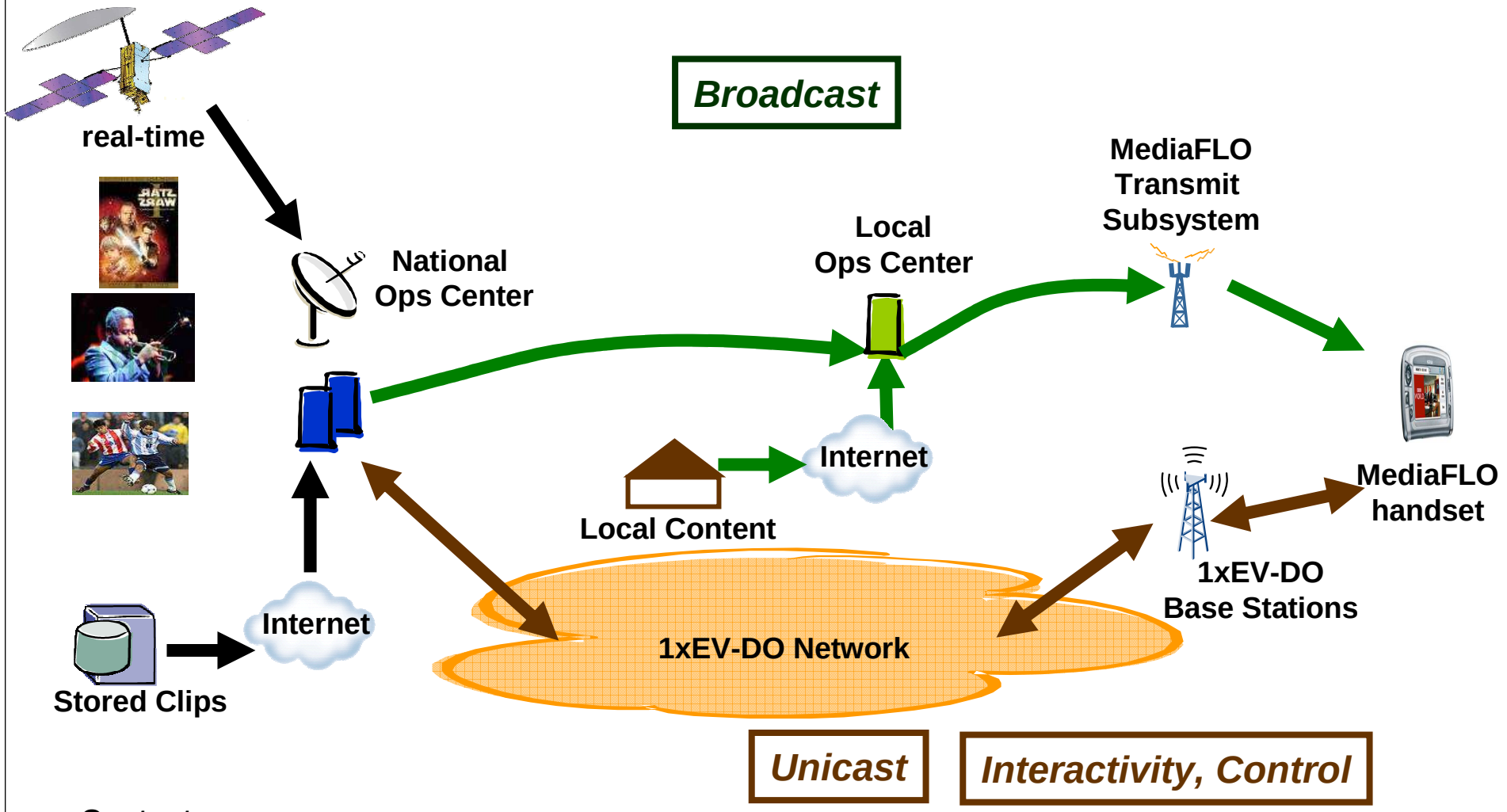
3G Broadcast/Multicast

- 3GPP2-**BCMCS** (Gold)
  - Broadcast and Multicast Services using 1xEV-DO
- 3GPP2-**eBCMCS** (Platinum)
  - Broadcast and Multicast Services using 1xEV-DO Rev A
  - Adds streaming capability to Gold
- 3GPP-**MBMS**
  - Multimedia Broadcast Multicast Services in UMTS
  - Using HSDPA and UMTS data

Broadcast Standards based on OFDM

- **DVB-H:** Digital Video Broadcasting standard, DVB-T, adapted for handhelds
  - Used in Europe
- **FLO:** Qualcomm's proprietary network Forward Link Only
  - nation wide US launch, international trial success
- **ISDB-T:** Integrated Service Digital Broadcasting – Terrestrial
  - used in Japan, evaluated in Brazil
- **DMB:** Digital Multimedia Broadcasting
  - Used in Korea, indoor coverage problems. Satellite-DMB

Qualcomm MediaFLO Architecture



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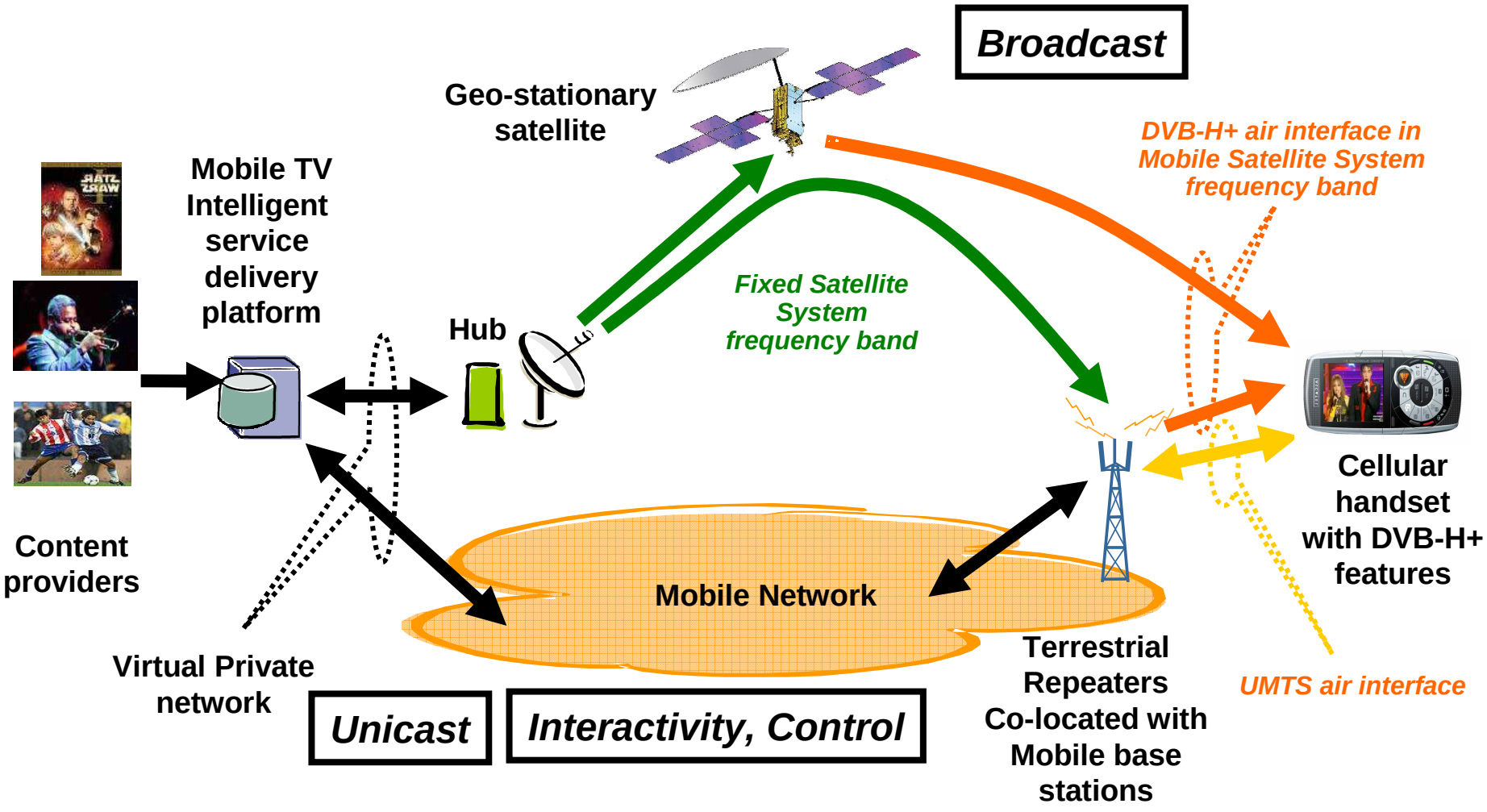
Alcatel-Lucent (DVB-SH) Hybrid Satellite/Terrestrial Solution



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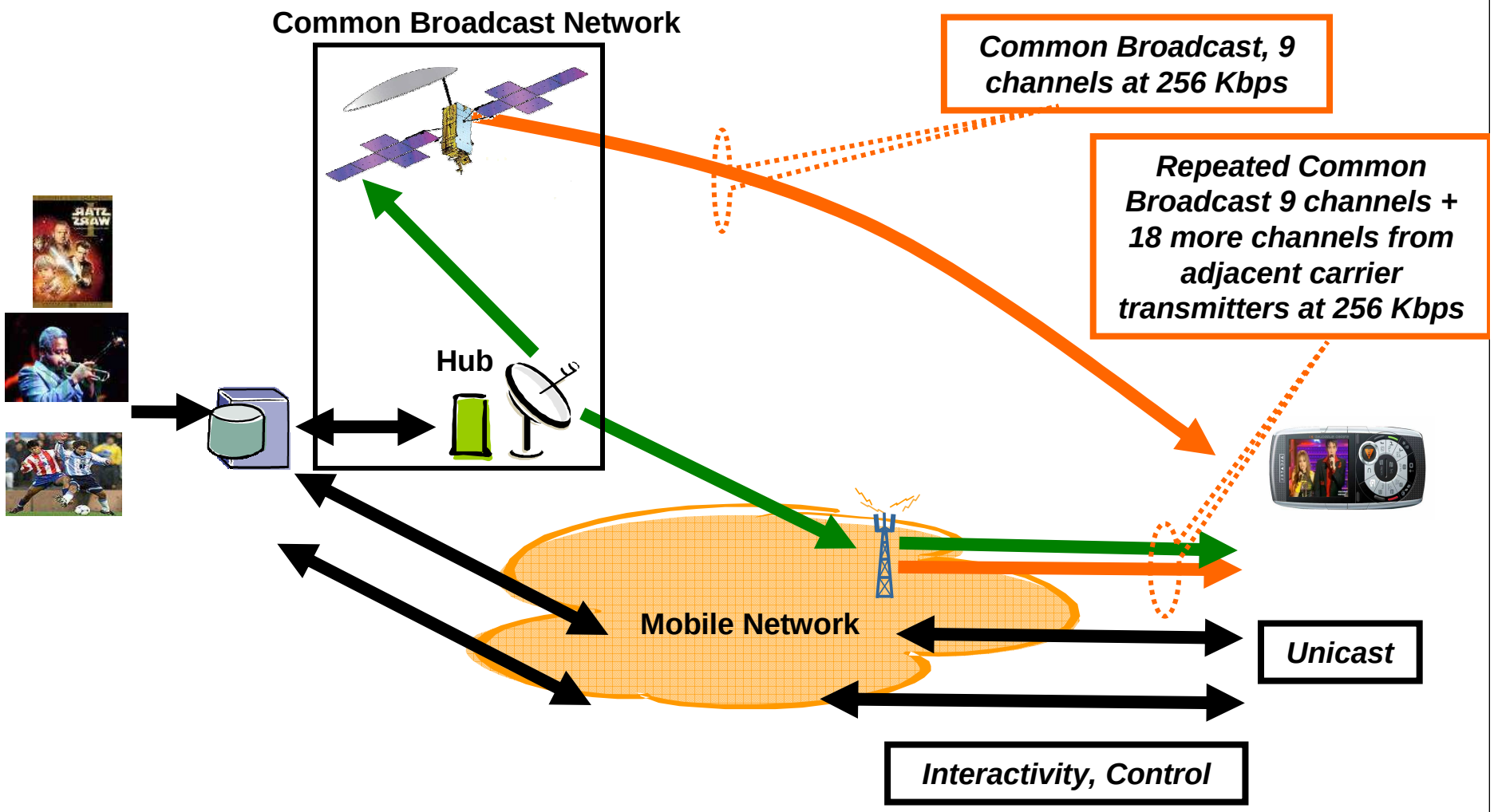
System Capacity for Alcatel-Lucent DVB-SH Solution



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Industry Trend

Balance Broadcast, Multicast and Unicast

Dedicated Mobile TV Broadcast Networks:

- DVB-H, DVB-SH, FLO
- channel lineup should be relatively static
- Eg. Cover top 30 markets in US

3G BCMCS/MBMS:

- Regional contents
- Location-based services and subscription-based services
  - News, weather, sports, file download
- For urban area, used for special events, gap filler
- For rural area regular channels because of limited resources

Unicast:

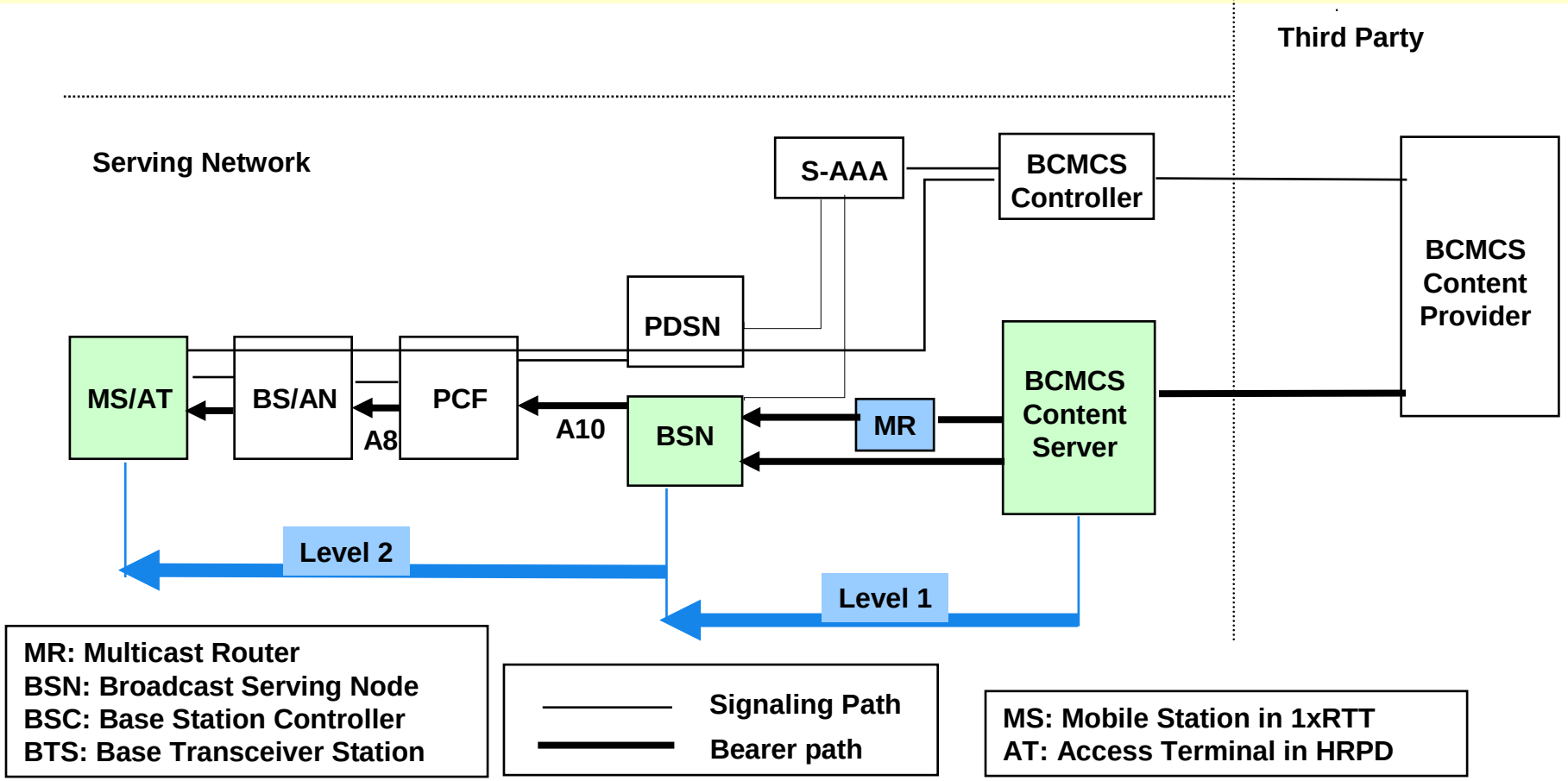
- Individual service
- 3G Base Station Controller (BSC/RNC) selects between unicast and multicast for each cell

3G Multicast Standards

Current 3GPP2 BCMC Service Architecture

Two-Level Multicast Hierarchy:

- **Level 1: IP Multicast/Unicast from Content Server to BSN within Core Network**
- **Level 2: Uni-directional Link Level Multicast from BSN to MS/AT**



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Current BCMCS Framework

Content Server provides video encoding for each live program in real-time, for scheduled program ahead of time

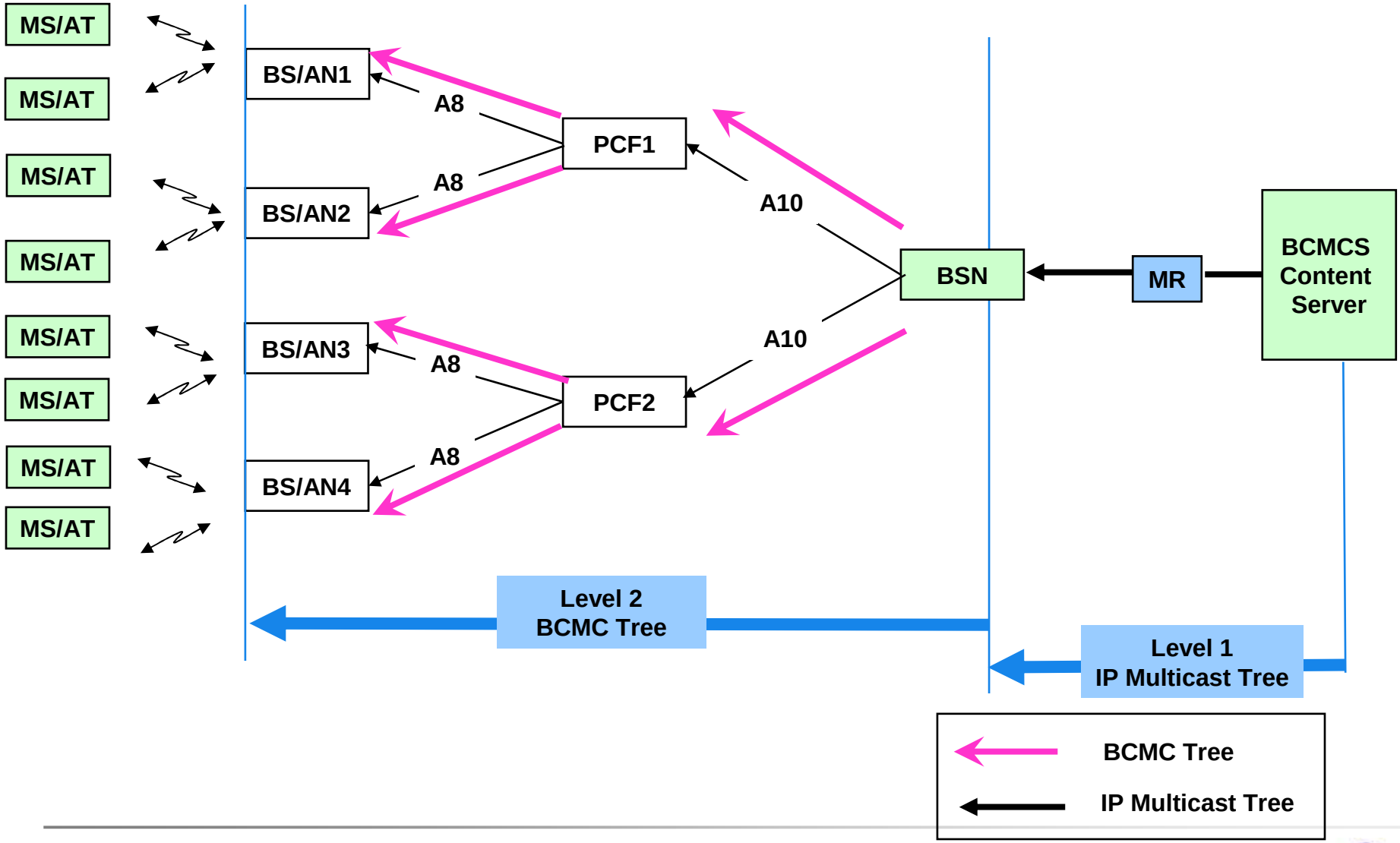
Application level FEC is applied to the encoded video stream at Content Server

Content Server multicasts each program to a number of BSNs either using IP multicast where BSNs are leaves or using dedicated IP tunnels with unicast

MS/ATs interested in the program form a link level BCMC tree (also called a BCMCS channel) rooted at the BSN that is multicasting the program

MS/ATs can join and leave a BCMC tree dynamically

Bearer Path Architecture -- Link Level BCMC Tree



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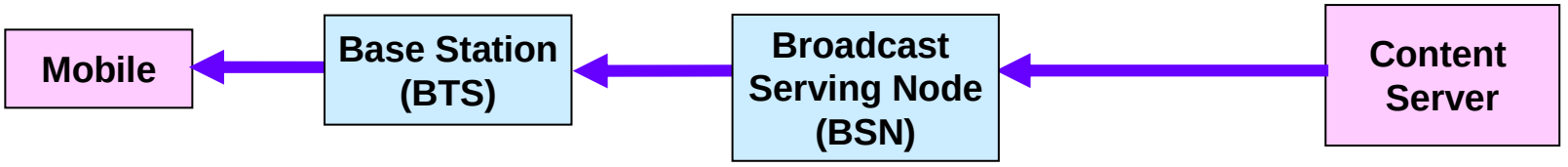
Issues with Current BCMCS Approach

No feedback from the MS/AT to the BTS, BSN or Content Server. As a result,

- Once the MS/AT joins a BCMC channel/group, it will receive the multimedia stream (IP flow) with fixed video encoding and fixed FEC protection
- Physical layer data rate for a BCMC channel is predetermined by the C/I ratio of the mobile at the edge of the cell regardless of the mobile's presence in order to satisfy every potential mobile in the coverage area

A base station might have multiple carrier frequencies while a mobile typically only listens to one (based on a hashing algorithm)

- If BCMCS is on another carrier than the one the mobile is listening to, need to ask mobile to switch
- If a page needs to be delivered, the mobile might be on a different carrier than the one dictated by the hashing algorithm



3GPP2 BCMCS References (www.3gpp2.org)

3GPP2 A.S0019-0 v1.0, Interoperability Specification (IOS) for Broadcast Multicast Services (BCMCS).

3GPP2 C.S0054-0 v1.0, CDMA2000 High Rate Broadcast-Multicast Packet Data Air Interface Specification.

3GPP2 S.R0030 v1.0, Broadcast and Multicast Service - Stage 1.

3GPP2 S.R0030-A v1.0, Broadcast and Multicast Service - Stage 1, Revision A.

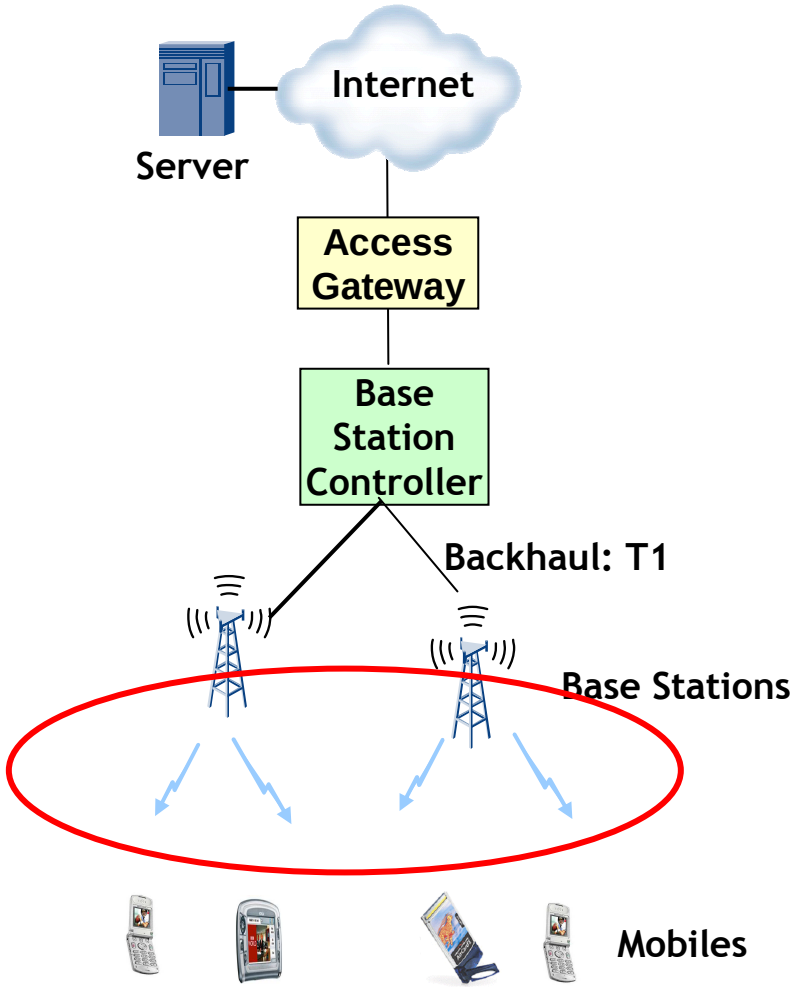
3GPP2 S.R0083-0 v1.0, Broadcast-Multicast Service Security Framework.

3GPP2 S.S0083-A v1.0, Broadcast-Multicast Service Security Framework.

3GPP2 X.S0022-0 v1.0, Broadcast and Multicast Service in cdma2000 Wireless IP network.

3G Multicast Scheduling

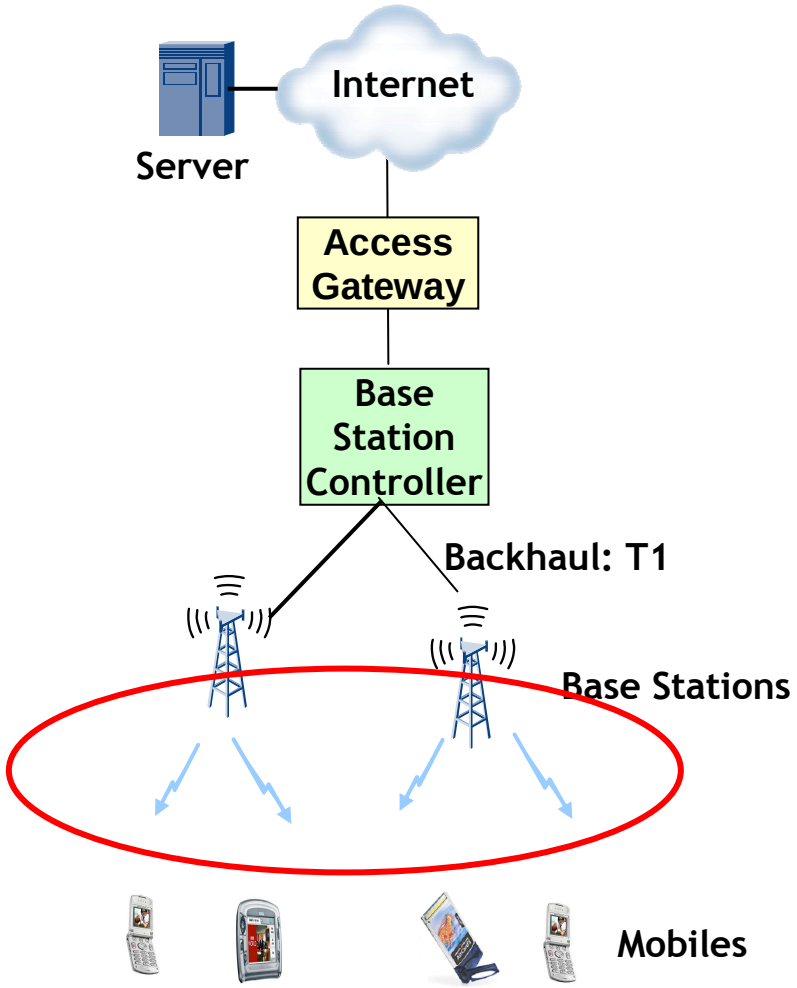
3G Data Network Architecture



Scarce bandwidth at wireless link air interface (between BS and Mobile)

→ Scheduling is important

3G Data Network Architecture



MAC layer scheduler on the Base Station

→ Independent scheduling decision at each Base Station

Downlink scheduling for TDM based systems

- CDMA 1xEV-DO
- UMTS HSDPA

Downlink MAC Layer Scheduling (CDMA1x Ev-DO/Data Only)

Serve one user at a time

Chosen user gets all system resources

Data rate depends on signal quality, varies between 36.4Kbps—2.4Mbps

Our focus: MAC layer scheduling for downlink multicast channels

Examples of 3G Multicast Applications

Location-based services:

- traffic reports, weather reports, …

Subscription-based services:

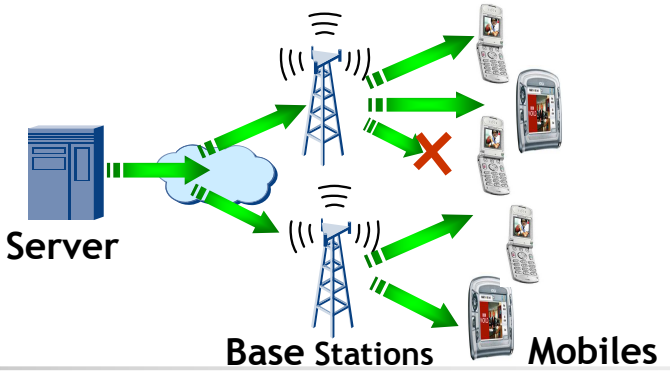
- news clips, TV clips, movie clips, …

Targeted live event coverage with user chosen views:

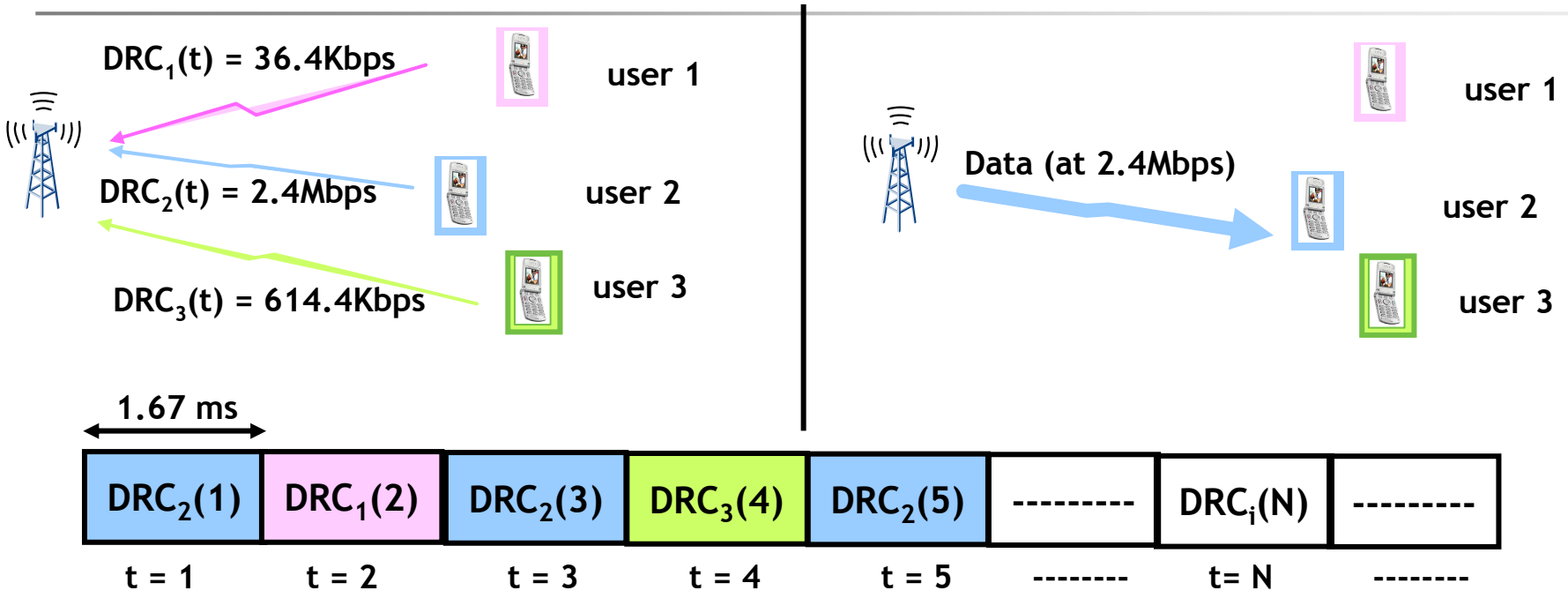
- At race car events, multicast multiple video feeds from drivers to local audience. Users can select their favorite drivers to watch.
- At concerts, multicast multiple video feeds from various cameras to local audience. Users can select their favorite views to watch.

Bulk data transfer:

- cooperative download



TDM MAC Layer Scheduling



Time divided into 1.67ms slots (600 slots/sec)

Mobile User:

- Measures downlink signal-to-noise ratio (SNR), calculates rate at which it can receive data
- Informs base station in a Data Rate Control (DRC) message to indicate the maximum feasible data rate (all or nothing)

Unicast scheduler chooses mobile user based on DRC values

Example Unicast Schedulers

Round Robin:

- channel state oblivious
- equally shares time slots among all mobile users
- potentially low system throughput (inefficient)

Max Rate:

- selects mobile user with the highest DRC value every time slot
- maximizes system throughput
- mobile user with low DRC values starves (unfair)

Proportional Fair (PF):

- serves users with higher instantaneous rates while maintaining fairness
- balances system efficiency and fairness
- baseline EV-DO downlink unicast scheduler

Unicast PF Scheduler

In time slot ***t***:

- choose **user *i*** to serve at **rate $DRC_i(t)$**
- compute exponentially weighted average throughput for each user
- $r_i(t)$ = service rate to user ***i***
  - either ***0*** or $DRC_i(t)$

T_i = long term throughput of user ***i***

Serve user with the largest instantaneous rate relative to its long term throughput

$$\arg\max_{i \in users} \left(\frac{DRC_i(t)}{T_i(t)} \right)$$

Unicast PF Scheduler Properties

Opportunistic Scheduling:

- serve users whose DRC values are high

User Oblivious:

- doubling throughput of user ***i*** has the same effect as doubling throughput of user ***j***.

Maximizes:

$$\sum_{i \in users} \log(T_i)$$

T_i = long term throughput of user ***i***

3G Multicast System Model (Single Base Station)

A user belongs to one or more multicast groups

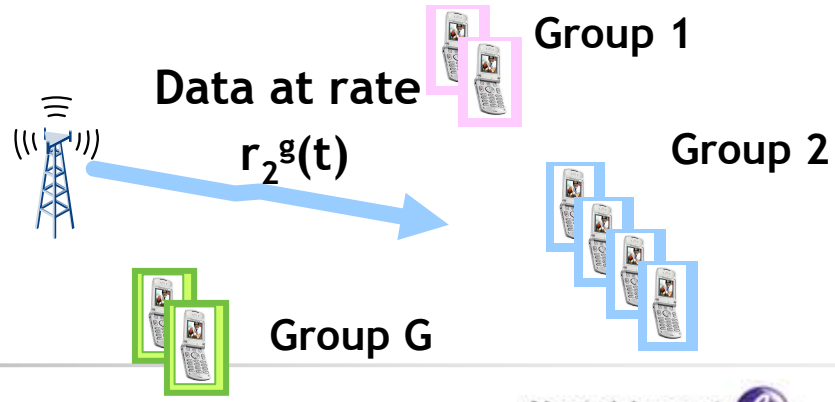
User sends DRC feedbacks to base station (as in unicast)

At each time slot t, scheduler decides to send data to group i with transmission rate:

$$r_i^g(t)$$

A scheduler needs to decide at each time slot:

- *what **data rate*** to transmit to each group
- *which **group*** to transmit to



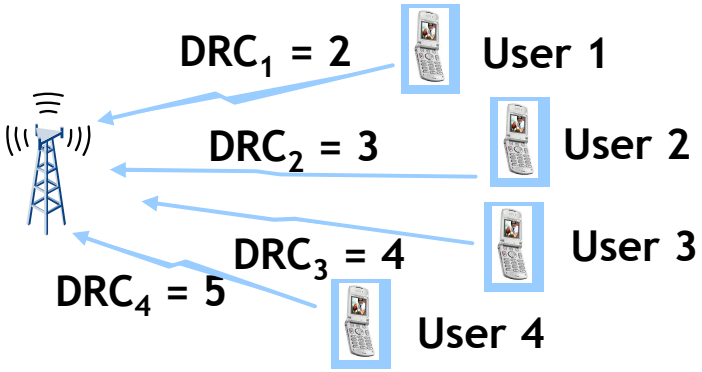
All or Nothing Effect at Mobile User

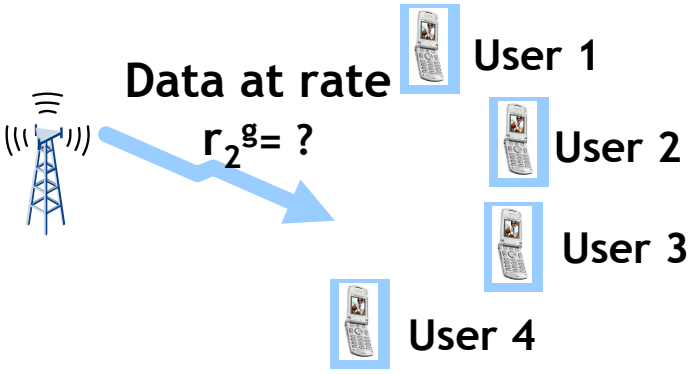
Transmission rate $\leq$ user DRC value, user receives all information

Transmission rate $>$ user DRC value, user can decode nothing

Scheduler will pick one of 2, 3, 4, 5 as the transmission rate

At what rate should the BS transmit?





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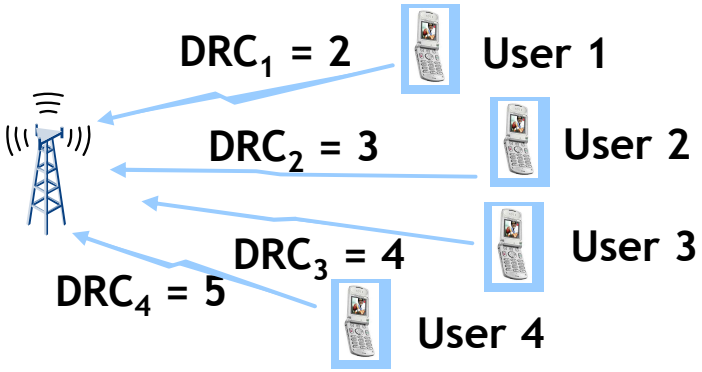
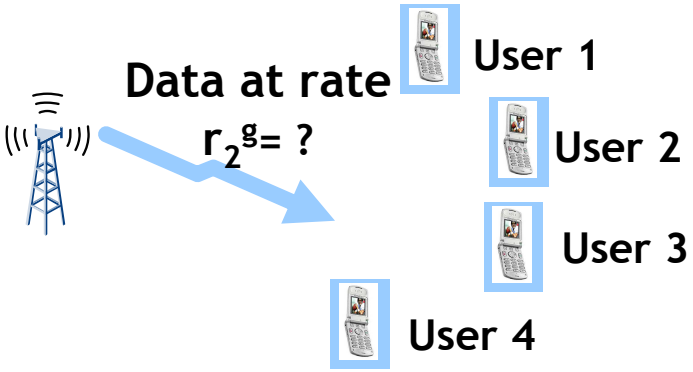
Aggregate Group Data Rate

Definition: sum of individual user (receiving) data rate

Example:

Xmit Rate	User 1 Recv Rate	User 2 Recv Rate	User 3 Recv Rate	User 4 Recv Rate	Agg. Rate
5	0	0	0	5	1x5=5
4	0	0	4	4	2x4=8
3	0	3	3	3	3x3=9
2	2	2	2	2	4x2=8





Possible Multicast Schedulers (I)

Fixed Rate Round Robin: (existing solution)

- Channel state oblivious
- Constant low rate to transmit to each group providing adequate cell coverage, rate limited by users at cell edge
- Equal share of time slots among all groups **(fair)**
- Low system throughput **(inefficient)**

Possible Multicast Schedulers (II)

Min Rate: (new proposal)

- Assign lowest user DRC as group rate
- Select one group with the highest aggregate rate relative to its group throughput
- Drawbacks: low system throughput, users with good channel conditions are limited by the worst user in the group **(inefficient)**

Xmit Rate	Aggr Rate
5	5x1=5
4	4x2=8
3	3x3=9
2	2x4=8

Max Rate: (new proposal)

- Assign feasible rate to each group to maximize its aggregate rate
- Select one group with the highest aggregate rate
- Drawbacks: group with low aggregate rate starves **(unfair)**

Xmit Rate	Aggr Rate
5	5x1=5
4	4x2=8
3	3x3=9
2	2x4=8

Design New Multicast Schedulers

Problem:

- Can we do better than *Fixed Rate*, *Min Rate* and *Max Rate ?*
  - they are either unfair or inefficient
- How to define “fair”

- How to **use channel conditions** to decide at each time slot:
  - what *data rate* to transmit to each group
  - which *group* to transmit to

How Should Fairness in Multicast be Defined

Define

- PF across groups: Inter-group PF (IPF)
  - balance efficiency and fairness among groups
- PF across users: Multicast PF (MPF)
  - balance efficiency and fairness among individual users

Compute exponentially weighted average throughput for each user (as in unicast PF)

T_i : Long term throughput of user i

Compute group throughput as sum of individual user throughput

T_k^g : Long term throughput of group k

Inter-group Proportional Fair (IPF) Scheduler

Intuition:

- **Step 1:** assign feasible rate to each group to maximize its aggregate rate
- **Step 2:** select one group with the highest aggregate rate relative to its group throughput

Properties:

- PF across groups

$$\max \sum_{k \in groups} \log(T_k^g)$$

Applications:

- Delay tolerant cooperative data download

Multicast Proportional Fair (MPF) Scheduler

Intuition:

- **Step 1:** assign feasible rate to each group to maximize its weighted aggregate rate
  - use $\left(\frac{1}{T_i}\right)$ as weight for user ***i***
- **Step 2**: select one group with the highest weighted aggregate rate

Properties:

- PF across individual users

$$\max \sum_{i \in users} \log(T_i)$$

Applications:

- Multimedia content distribution with layered encoding

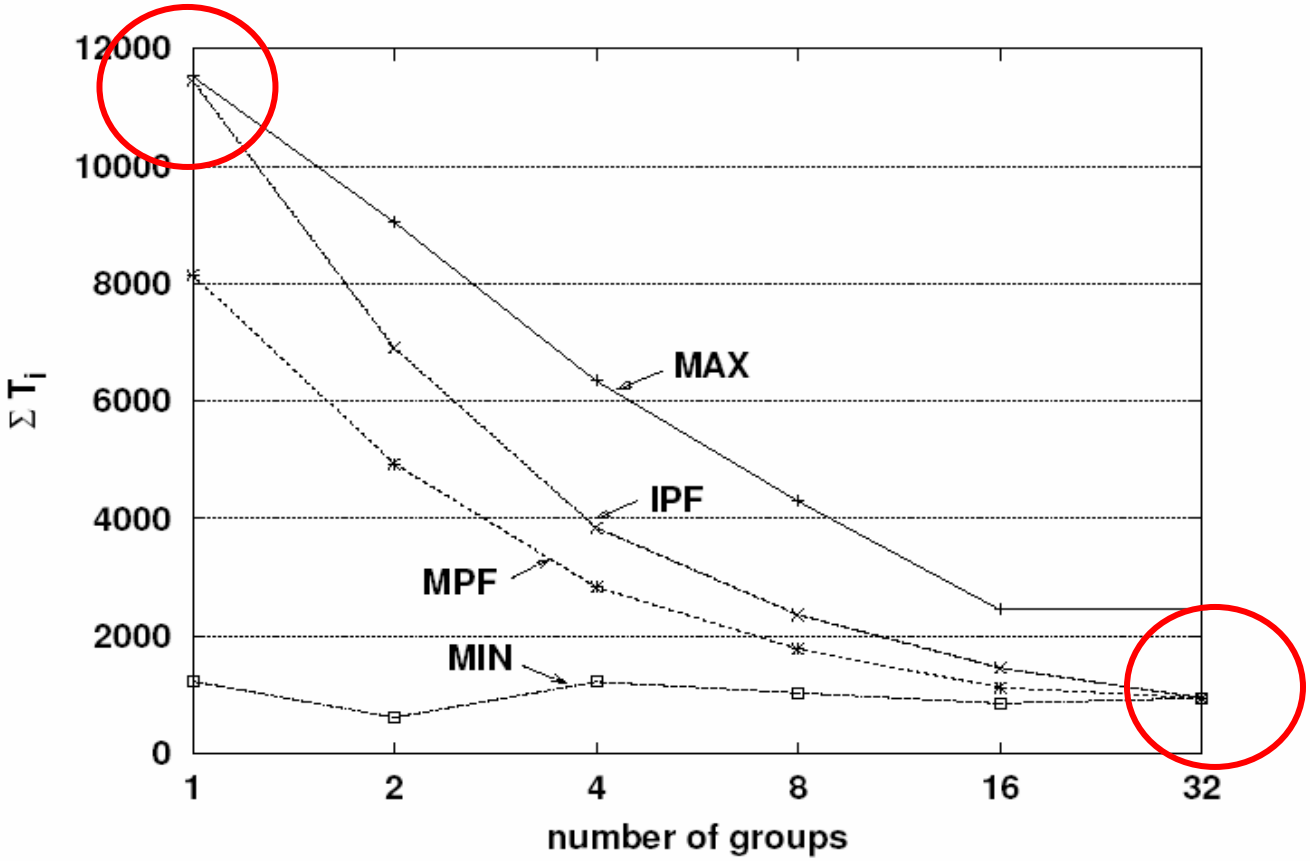
Properties of 3G Multicast Schedulers

Alg	Rate $r_k^g(t)$	Group $k(t)$	Objective
IPF	$\arg\max_y \phi_{k,t}(y)$	$\arg\max_k \frac{\phi_{k,t}(r_k^g(t))}{T_k^g(t)}$	$\max \sum_k \log(T_k^g)$
MPF	$\arg\max_y \varphi_{k,t}(y)$	$\arg\max_k \varphi_{k,t}(r_k^g(t))$	$\max \sum_i \log(T_i)$
MAX	$\arg\max_y \phi_{k,t}(y)$	$\arg\max_k \phi_{k,t}(r_k^g(t))$	$\max \sum_i T_i$
MIN	$\min r_{n,k}(t)$	$\arg\max_k \frac{S_k(r_k^g(t))}{T_k^g(t)}$	

1 group only: IPF = MAX

1 user per group: IPF = MPF = MIN = PF for unicast

Simulation Results (Obj = sum of T_i)



32 users within a cell

Alg	Objective
IPF	$\max \sum_k \log(T_k^g)$
MPF	$\max \sum_i \log(T_i)$
MAX	$\max \sum_i T_i$

1 group only: IPF = MAX

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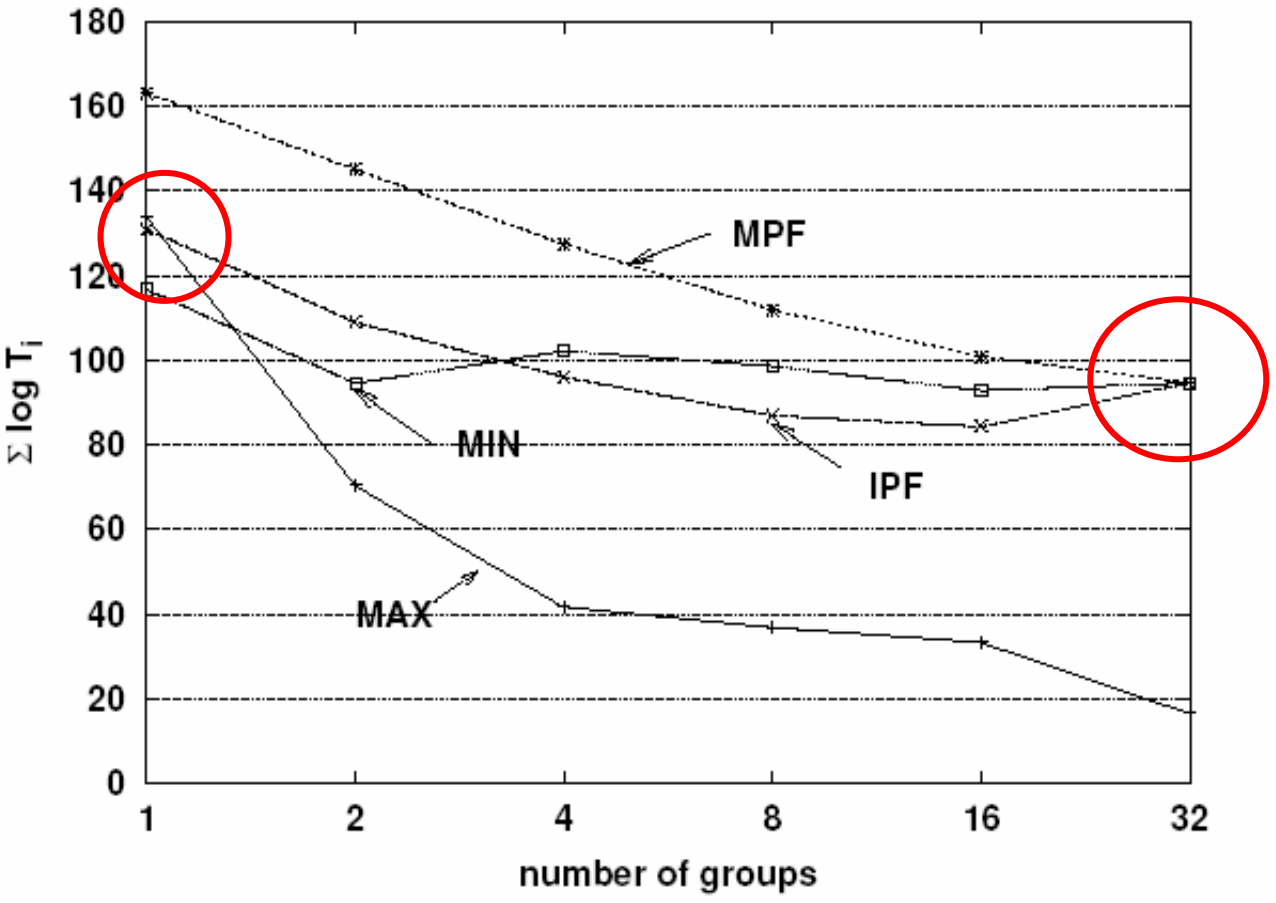
Simulation Results (Obj = sum of $\log(T_i)$)



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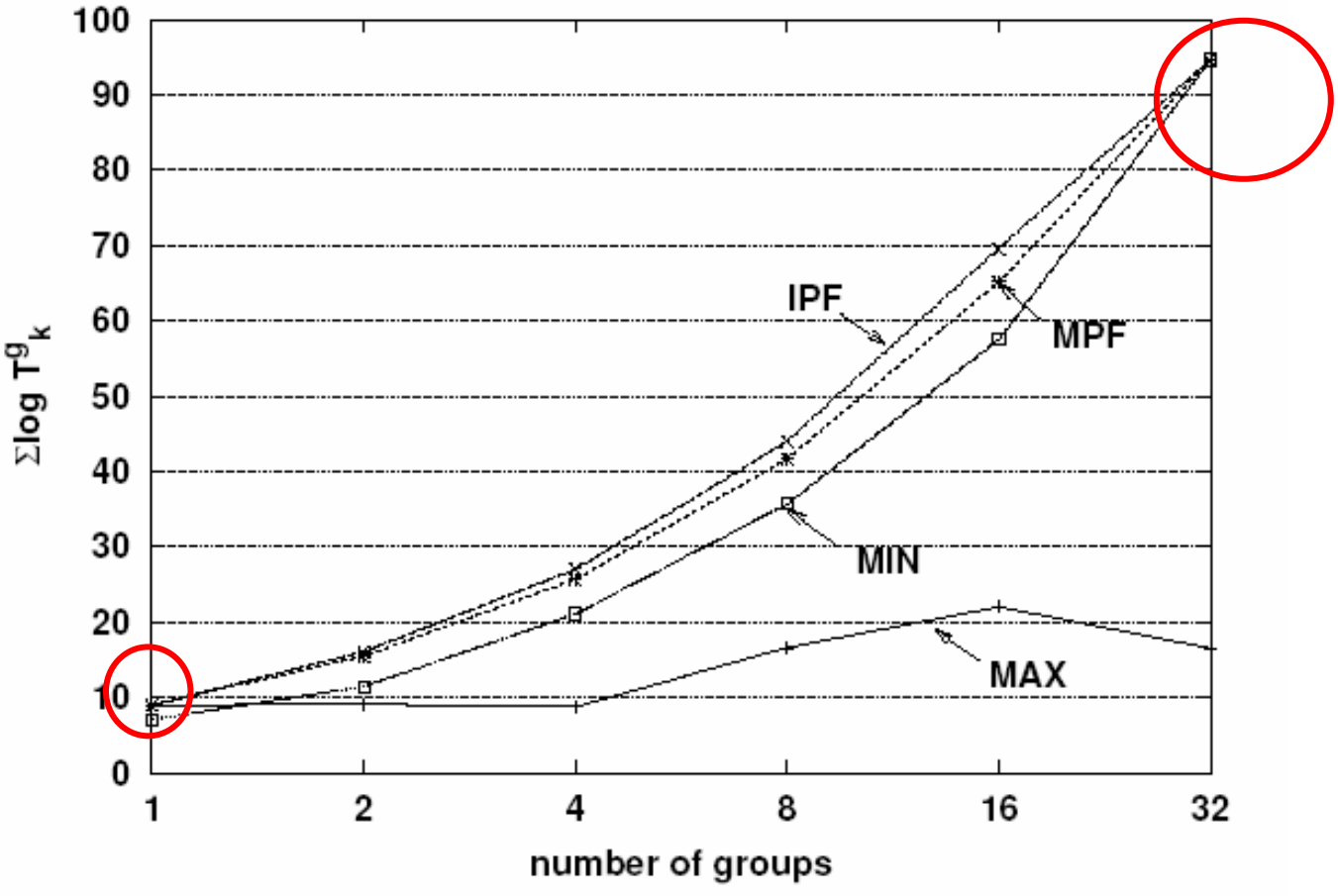

32 users within a cell

1 group only: IPF = MAX

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Alg	Objective
IPF	$\max \sum_k \log(T_k^g)$
MPF	$\max \sum_i \log(T_i)$
MAX	$\max \sum_i T_i$

Conclusion and Future Work

Proposal of two PF multicast schedulers:

- Inter-group PF (IPF): PF across all groups
- Multicast PF (MPF): PF across all users

Both achieve good balance between **fairness** and **efficiency** (system throughput)

Proof of the PF property of IPF and MPF

Future work:

- Ensure QoS for multicast
  - max and min throughput
  - delay bound

Reference:

- H. Won, H. Cai, D.Y. Eun, K. Guo, A. Netravali, I. Rhee and K. Sabnani, "Multicast Scheduling in Cellular Data Networks", in *Proc of IEEE INFOCOM'07*, May 2007.

Thank You