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UTRAN Enhancements for Multicast

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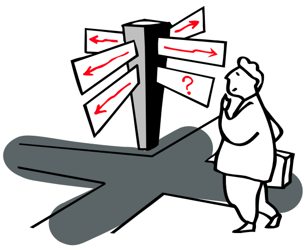
Outline

- Introduction
- Protocol Enhancements
- Power Control Enhancements
- Conclusion



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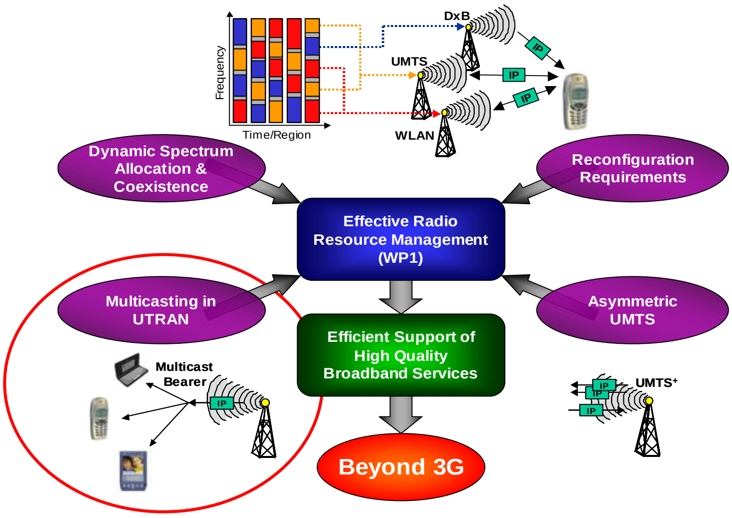
Workpackage 1: Spectrum Efficient Radio Resource Management



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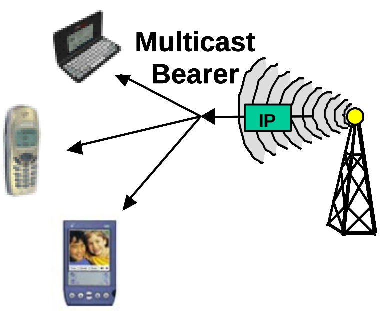
Multicast over UTRAN - Motivation



- The radio channel is a shared and limited resource
- Multiple point-to-point transmissions of the same high-bandwidth content are inherently inefficient
- Currently only point-to-point communication is supported by the radio interface
- If the service allows it to bundle user requests in time and space a point-to-multipoint transmission would be much more spectrum efficient

Multicast over UTRAN - Objectives

- Development and proposal of UTRAN enhancements to provide spectrum efficient multicast services
  - Power Control
  - Radio Resource Management
  - Protocol extensions
  - Transmission techniques
- Comparison and Analysis of Multimedia Broadcast/Multicast Service (MBMS) approach
- Validations of the benefits by simulations
- Simulative performance evaluation of UTRAN based multicast with respect to
  - Spectrum efficiency
  - Quality of Service (QoS)

Multicast over UTRAN – Concept

- Use of existing channels with minor modifications (e.g. multicast addressing)
  - Dedicated Channel (DCH)
  - Forward Access Channel (FACH)
  - Downlink Shared Channel (DSCH)
  - High Speed Downlink Shared Channel (HS-DSCH)
- Development of new multicast Radio Bearers
- Elaboration and qualitative analysis of multicast using new concepts
  - Orthogonal Frequency Division Multiplexing (OFDM)
  - Hybrid ARQ (HARQ)

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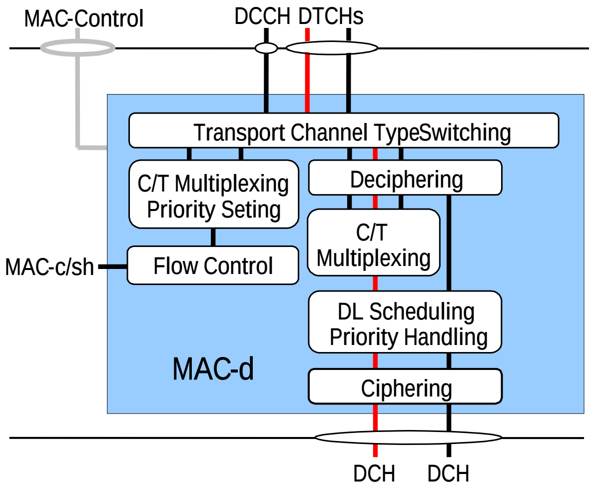
Dedicated Channel (DCH)

- Point-to-point communication
- Reception only in connected mode
- Option to use acknowledged mode in RLC
  - Better QoS if higher channel capacity available
- MAC header overhead
  - 0 bit
  - 4 bit if additional services are multiplexed



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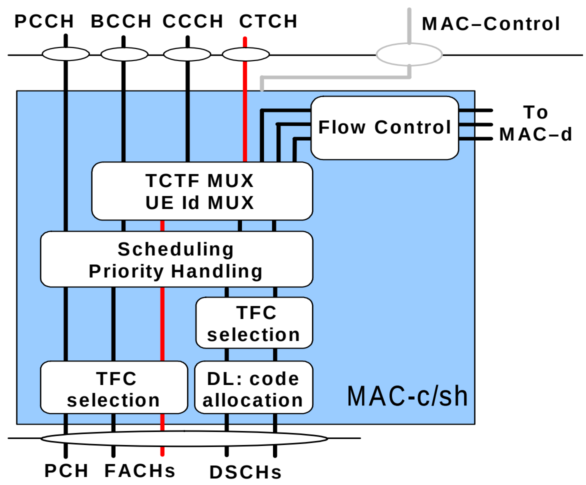
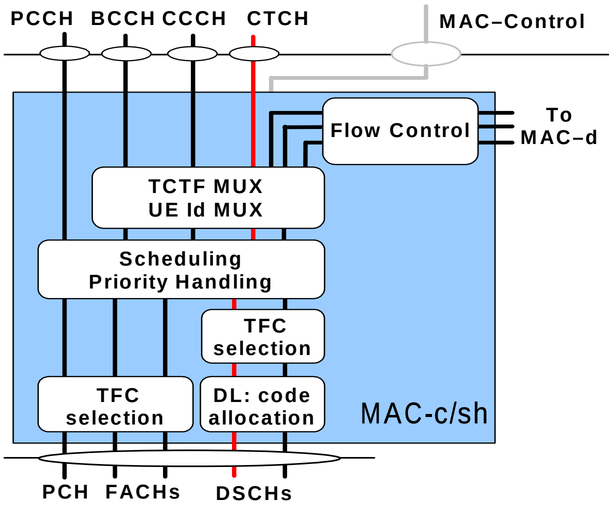
Forward Access Channel (FACH)

- Point-to-multipoint communication
- Reception also possible in idle mode
- Only unacknowledged mode available in RLC because of missing uplink channel
- MAC header overhead
  - 8 bit TCTF without group addressing in MAC
  - Approx. 20 bit if UE-Id used for addressing



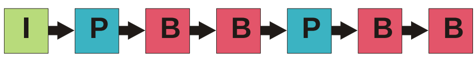
Downlink Shared Channel (DSCH)

- Could be used for point-to-multipoint communication with only minor extensions to the specification
- Without uplink signalling only RLC unacknowledged mode can be applied
- MAC header overhead
  - Approx. 18 bit if 16 bit UE-Id used for group addressing



Protocol performance comparison

- Minor difference in maximum throughput
  - DCH with unacknowledged mode
    - Higher throughput because of less header overhead (approx. 5% at 64 kbps and 128 kbps)
  - DCH with acknowledged mode
    - Maximum throughput is lower because of larger RLC headers, RLC status PDUs and retransmissions
    - On the other hand, the Quality of Service in terms of PDU loss is better
- Simulations using a typical multicast service (real-time video streaming) showed nearly identical results



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Physical characteristics

- Differences of the transport channels in the physical layer:

	DCH	DSCH	FACH
Outer Loop Power Control	✓	✓ ❶	✓ ❶
Fast Power Control	✓	(✓) ❷	✗
Soft Handover	✓	✗	✗

❶ uplink signalling using RACH or DCH for example
❷ if associated with a DCH
→various options to combine the power control commands

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Efficiency Factors

- A lot of trade-offs which influence the overall performance exist. Examples:

Multiple services on one multicast bearer, less codes used	↔	Header overhead for addressing and same transmission power for all multicast groups
Better QoS through RLC acknowledged mode	↔	Higher traffic, higher interference and of course point-to-point communication
Gain due to soft handover	↔	Additional code usage and point-to-point transmissions
Ability to use fast power control	↔	Additional signalling in uplink and therefore also in downlink
Frequent reconfiguration of system to more efficient setup	↔	Signalling to update the configuration of the UEs

- All above aspects are weighted differently depending on scenario in terms of number of users, receiving conditions and cell resource usage
- Mixture of point-to-point and point-to-multipoint communication depending on mobiles´ current receiving conditions may be most efficient

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Comparison DCH and FACH with fixed power setting

- The most straightforward way would be to use the FACH transmitted with a constant power over the cell
- The power level should be a trade off between cell coverage, interference increase and QoS of the multicast group
- Fixed power transmission cannot track variations in propagation and interference conditions
- One of the key points is the threshold for switching between multiple DCHs and one multicast FACH

Results:

- Investigations were performed considering a streaming service mapped onto a 64 kbps radio bearer
- For a FACH set to 4 W the threshold for switching is around 7 UEs per cell
- If target is 1% BLER for 98% the of UEs, 5 W are needed (30% of BS power for one service)
- Changing conditions regarding cell load can not be efficiently tracked

➔ Power control should be implemented

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Power Control in Multicast

- Power control adjusts the transmitted power dynamically in order to achieve the required QoS
- Power control helps to reduce the interference, hence it increases the capacity of the system
- A multicast channel generally requires a higher power than a unicast channel due to servicing of multiple UEs
- Power control in multicast channel aids in minimising the high power requirements
- Power control which considers the link of the weakest UE would still be more efficient than a high constant power (i.e. no power control)

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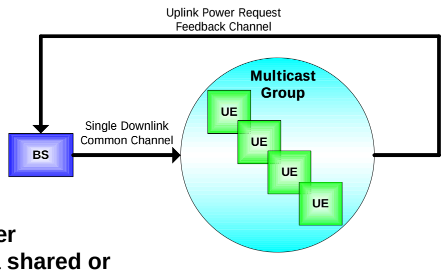
Power Controlled Multicast System

- BS transmits on a single common channel to all Multicast UEs
- Due to different physical locations of UEs, each experiences different fading and path loss characteristics
- The SIR is obtained at the UEs and a power request is sent back to the BS, either on a shared or dedicated uplink channel
- BS receives the feedback requests and uses an algorithm to determine the best transmission power level



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System Components

- Common downlink Multicast channel
  - Assumes channel to be similar to a dedicated downlink channel
    - Power controlled
    - Variable data rate
    - Channel not available to all UEs in cell – to restrict access for Multicast UEs only
- Uplink feedback channel
  - Could use either dedicated uplink or shared (RACH) channels
    - Low data rate transmission
    - However, it has limited capacity
- Propagation channel
  - Each UE experiences fast uncorrelated fading
  - Path loss and shadowing effects also depend on UE location

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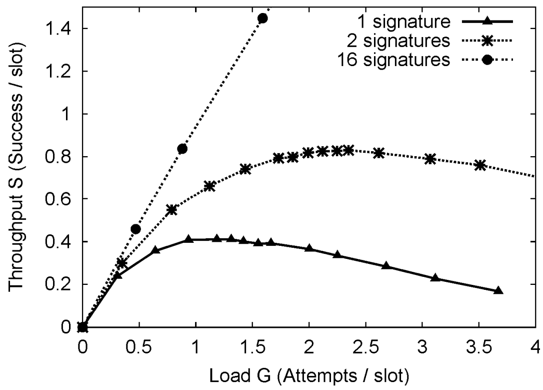
Random Access Channel (RACH)

- RACH is a Slotted-ALOHA channel with 16 non-colliding signatures
- Throughput can be calculated with equation below
  - S – normalized throughput
  - G – normalized total load
  - n – number of signatures
- Additional uplink data capacity available



$$S = G * e^{-\frac{G}{n}}$$

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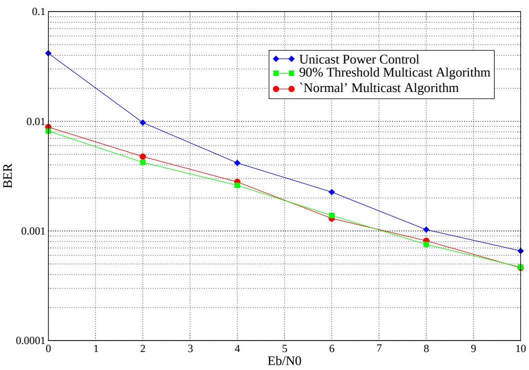
RACH Max Theoretical Capacity For System

- Power could be controlled to satisfy a certain percentage of UEs in order to trade off coverage vs transmission power
  - This results in certain number of UEs in outage
- To reduce the number of transmissions on the uplink, only UEs that require higher power sends uplink request
  - This results in certain number of UEs always sending uplink requests
- Probability of collision increases with higher number of transmissions
  - Could result in lower than actual number of power request received by BS, resulting in less than required percentage of satisfied UEs
- Assuming all 16 signatures and 15 slots in 20ms frame can be used in RACH, the collision probability (hence reliability), and maximum number of users supportable is tabled

No. of transmissions on RACH (X)	Collision Prob (n)	Reliability (1-n)	Satisfaction Percentage					
			98%	95%	90%	85%	80%	75%
			Maximum Number of users					
2	0.0041667	0.9958333	99	39	19	13	9	7
3	0.0124653	0.9875347	149	59	29	19	14	11
4	0.0248095	0.9751905	199	79	39	26	19	15
5	0.0410626	0.9589374	249	99	49	33	24	19
6	0.0610405	0.9389595	299	119	59	39	29	23
7	0.0845145	0.9154855	349	139	69	46	34	27
8	0.111216	0.888784	399	159	79	53	39	31
9	0.140842	0.859158	449	179	89	59	44	35
10	0.173061	0.826939	499	199	99	66	49	39
11	0.207516	0.792484	549	219	109	73	54	43
12	0.243839	0.756161	599	239	119	79	59	47
13	0.281647	0.718353	649	259	129	86	64	51
14	0.320558	0.679442	699	279	139	93	69	55
15	0.360192	0.639808	749	299	149	99	74	59
16	0.40018	0.59982	799	319	159	106	79	63
17	0.440168	0.559832	849	339	169	113	84	67
18	0.479822	0.520178	899	359	179	119	89	71
19	0.518836	0.481164	949	379	189	126	94	75

- Green line shows the average received BER for 90% satisfied UEs
- Red line shows the average received BER for 100% satisfied UEs
- Received quality for multicast is better than unicast, due to increased average transmit power
- With lower percentage of satisfied UEs, the average transmit power can be reduced



- The graph shows that reducing the percentage of satisfaction has minor effects on the average received quality. However it should be able to reduce the transmit power, at the expense of sacrificing some users into outage

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Conclusion

- Validation of protocol enhancements for UTRAN multicast support
- Negligible difference in performance regarding radio interface protocols of data link layer
- Enhancements of UMTS power control mechanisms to support more efficient multicast transmissions
- Optimal multicast configuration heavily depends on scenario and current system situation

→ **UTRAN based multicast is worth to be applied as a spectrum efficient downlink radio bearer**

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Thank you!

Any questions?

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