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Network Based Seamless Mobility In Networks Of Future

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Networks Of Today

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- Before we go on with how the networks will look like in the future, let’s characterize the networks we face today.
- Networks we see today:
  - ISP Networks,
  - Cellular Operators,
  - Campus, Residential and Enterprise Networks,
  - Core Networks.

Networks of Today

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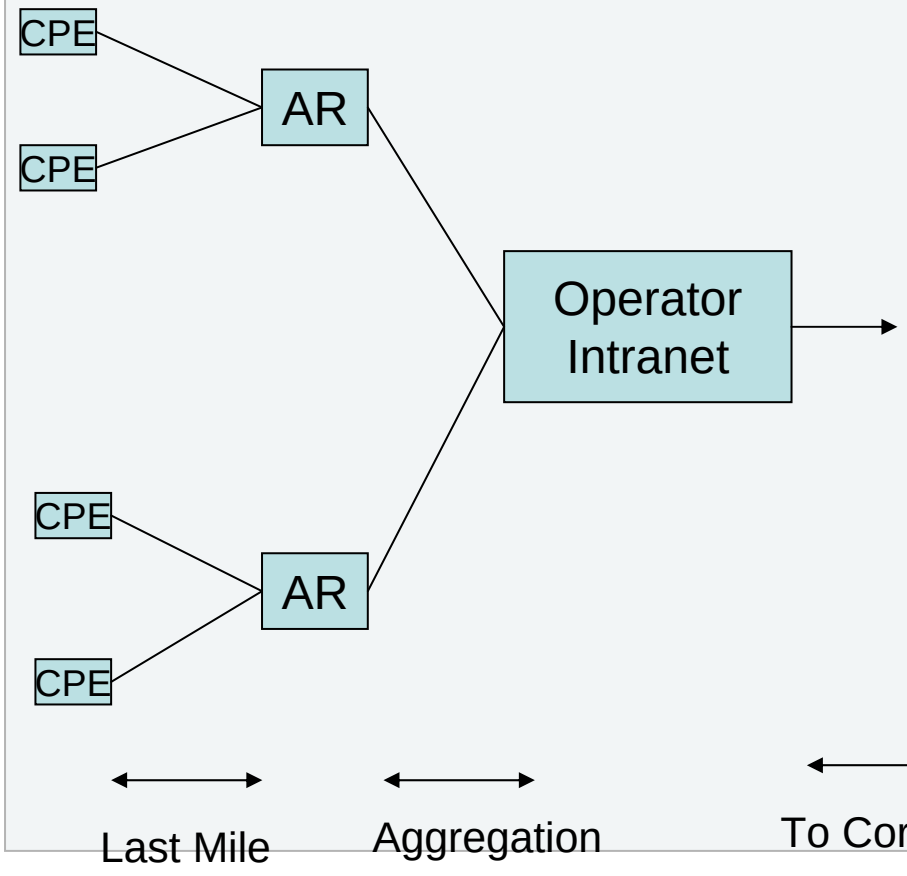
- ISP Networks:



•CPE: Customer Premises Equipment

•AR: Aggregation Router

•Last Mile: Twisted Copper, Fiber, Cable, Wireless (Flash OFDM, Wimax)

•Aggregation: Wired, Wireless (LOS), Microwave

•Core Network Connections: Optical, Fiber

Networks Of Today

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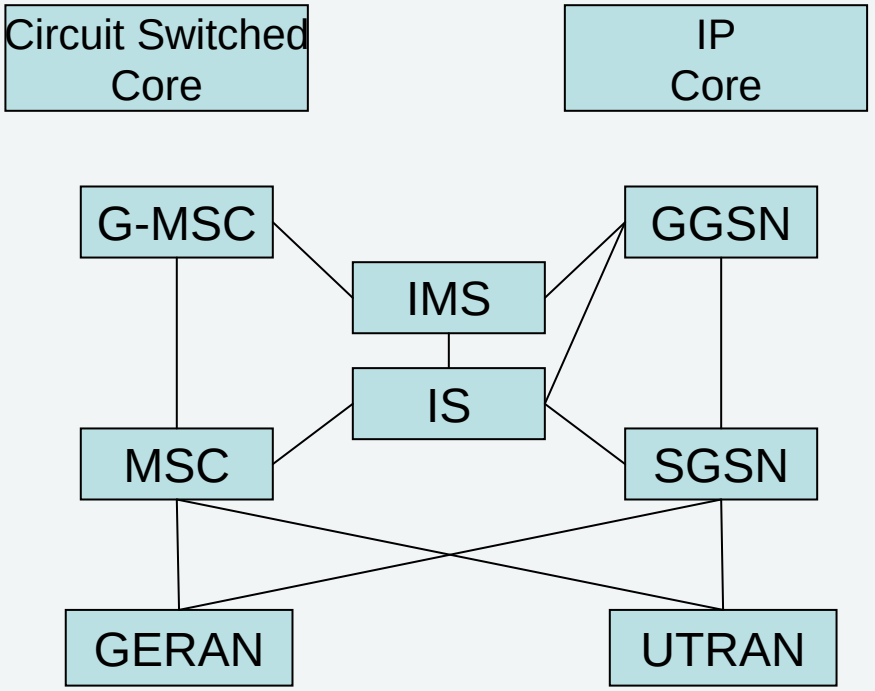
- Cellular Data Networks:



•Geran: GSM Base Stations and Controllers

•UTRAN: UMTS Base Stations and Controllers

•MSC: Mobile Switching Center

•GSN: GPRS Support Node

•IMS: IP Multimedia Subsystem

•IS: Shared Information Servers

Networks Of Today

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- Campus, Residential and Enterprise Networks are IP based networks with wired or wireless CPEs.
- Core Networks connect networks of different kinds. They are not visible directly to the users.

Networks Of Future

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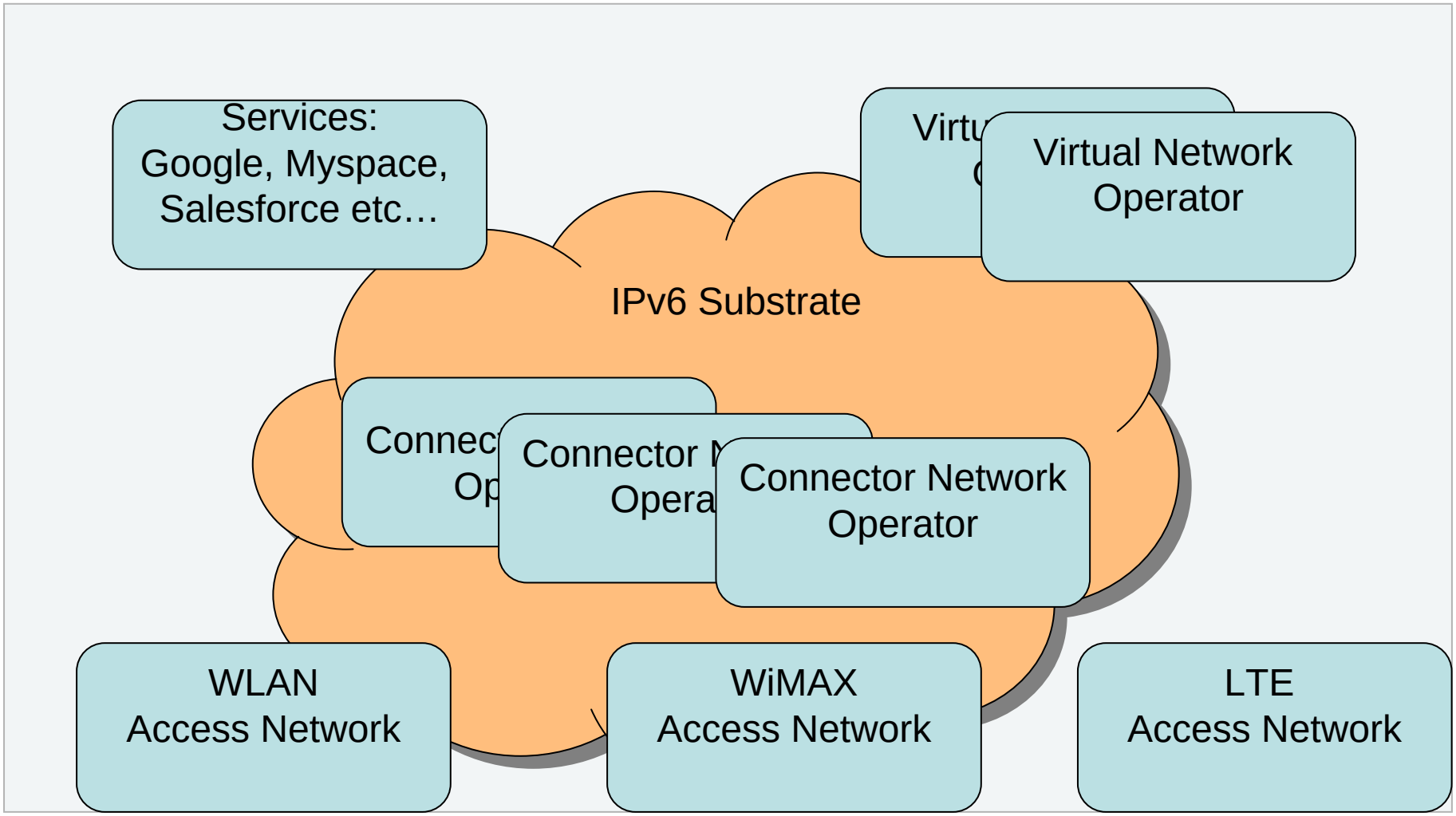

Networks Of Future

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- Not heterogeneous anymore, different access technologies.
- Operators would like to integrate different technologies in a seamless manner.
- All IP.
- But why can’t you use WLAN and UMTS interchangeably, yet?

Networks of Future

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- Integration poses 5 Main challenges:
  - Security,
  - QoS,
  - Charging,
  - Network Management,
  - Mobility.

Security Challange

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- Security challenge:
  - Each system has its own security approach,
  - Each new system brings in more unique vulnerabilities,
  - Identity.

QoS Challenge

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- QoS challenge:
  - Wireless QoS is very tricky, and handled differently in different networks:
    - WiMAX is connection oriented,
    - WLAN does not support it.
  - Different networks give different tools to deal with QoS:
    - Over-provisioning in UMTS
    - None in WLAN
  - How to link it to services, and how to give guarantees on different mediums?

Charging, Network Management

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- Charging Challenge:
  - AAA,
  - Metering.
- Network Management Challenge:
  - How to bring all the mentioned challenges into a single platform that is consistent and user friendly.
  - High costs of training.

Seamless Mobility Challenge

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- Users are mobile.
- The channel is mobile:
  - Multi-path fading causes the signal to degrade very fast.
- Services are “dynamic”:
  - Adaptive rates.
- Network conditions are dynamic:
  - Congestion.

Seamless Mobility Challenge

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- Mobility is any event that necessitates the change of Access Point (Point of Attachment) of a user in order to keep the agreed service quality.
- The user doesn’t actually have to move!

Types of Mobility

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- Terminal Mobility:
  - User equipment should be connected.
- User Mobility
  - User should be able to connect to the network even if he changes terminals.
- Service Mobility:
  - Services or data sessions towards a user should continue in an mobility event.

Seamless Mobility

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- Networks of tomorrow should:
  - support all types of mobility seamlessly,
  - that is without any or minimum user interaction.

Components of Mobility

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- Location Management,
- Delivery to Mobile End Points,
- Handovers,
- Network Access Control.

Location Management

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- Location Management: Users current PoA should be known at the network and user side:
  - Location Update: User informs regularly of its current PoA,
  - Location Discovery: Paging.

Delivery to Mobile End Points

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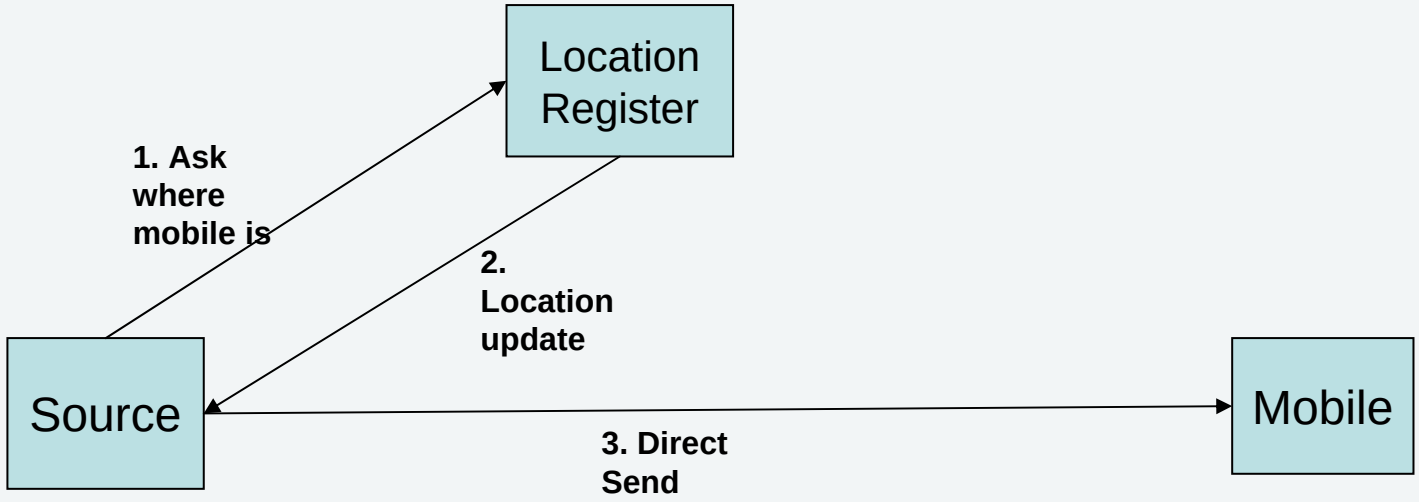
- Ultimate goal of mobility protocols.
- There are different strategies:
  1. Direct Delivery
  2. Relayed Delivery
  3. Hybrid

Direct Delivery



Direct Delivery

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- Advantages:
  - Most direct route will be chosen.
- Disadvantages:
  - Sender should discern mobile from non-mobile,
  - Sender should run a non standard protocol.

Relayed Delivery

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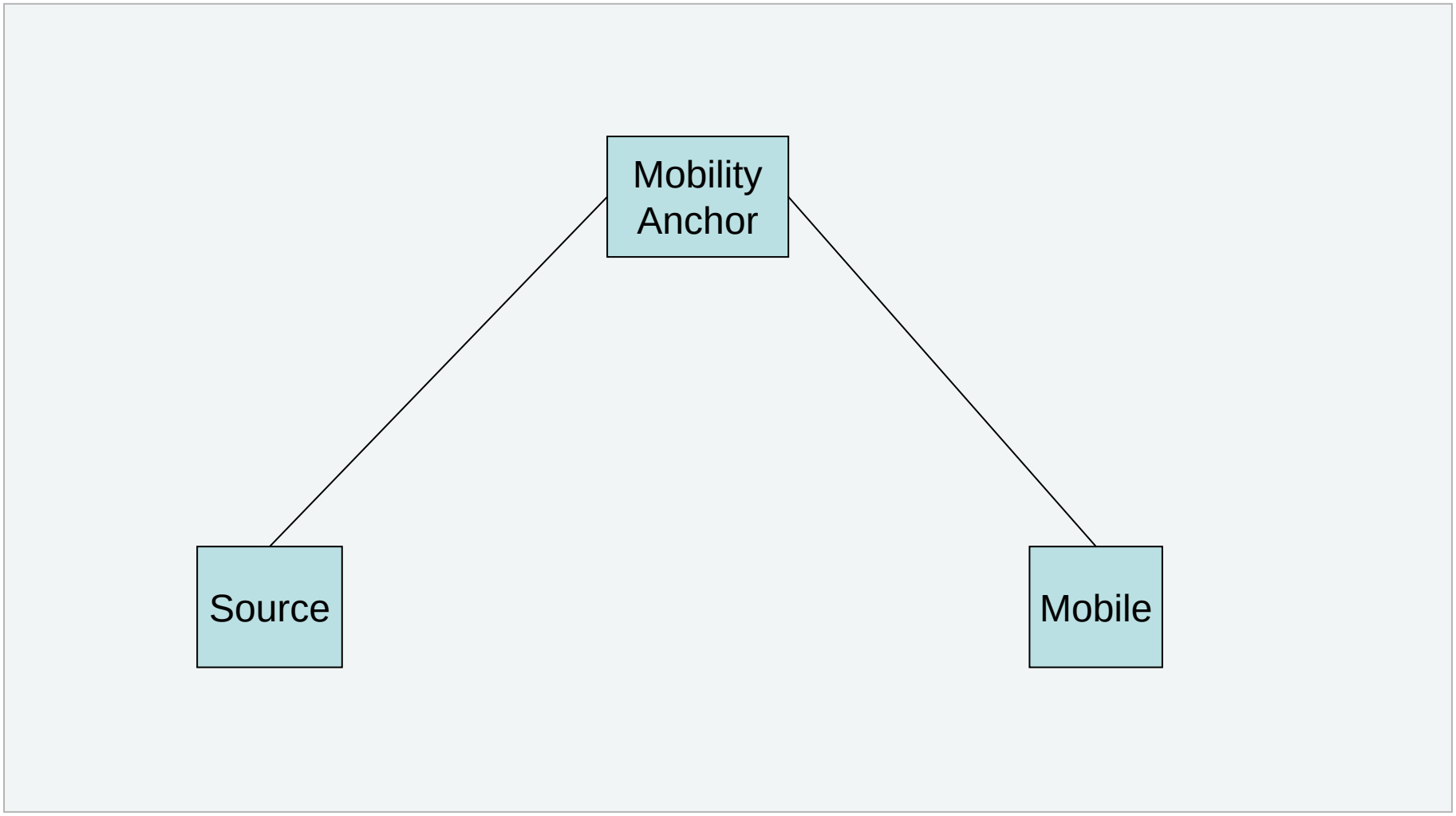

Relayed Delivery

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- Mobility anchor point intercepts all traffic, incoming and outgoing of the mobile user,
- And responsible for forwarding to the correct location.
- Advantages:
  - Source can be agnostic,
- Disadvantages:
  - Mobility Anchor Points can be bottlenecks,
  - Longer routes.

Hybrid

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- Initial packets are sent in a relayed manner.
- If the source is not agnostic, the rest can go directly.

Handovers

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- Changing the PoA.
- They occur in different layers:
  - Physical Layer Handover (L1),
  - Logical Link Layer Handover (L2),
  - IP Layer Handover (L3).
- All of these handovers can occur independently.
- They can occur on different ranges (intra- or inter-subnet handovers.

Handovers

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- There are different types of handovers.
- Hard Handovers:
  - Mobile users receive data from a single PoA.
  - Make Before Break,
  - Break Before Make.
- Soft handovers: Mobile receives data from multiple PoAs.
  - Diversity,
  - But there are synchronization issues.

Network Access Control

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- AAA:
- Authentication:
  - Network should authenticate that the user is actually who it claims to be.
- Authorization:
  - Once authenticated, network has to decide if the user is allowed to use the network resource.
- Accounting:
  - And he has to pay!

Layer 2 Handovers

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- Let us explore some L2 handovers:
  - WLAN,
  - WiMAX,
  - UMTS.

WLAN L2 Handovers

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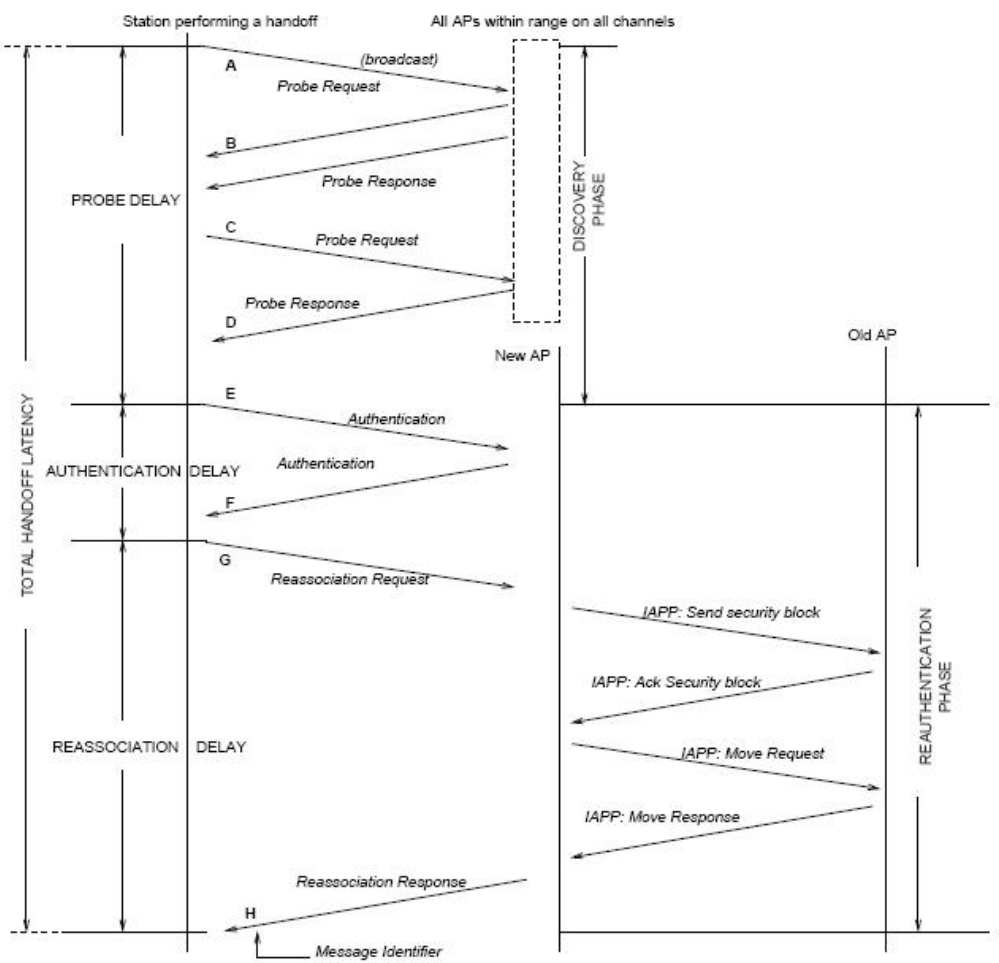

Figure 2: *The IEEE 802.11 Handoff Procedure (followed by most cards)*

WLAN L2 Handovers

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- Comments:
  - Purely user based,
  - IAPP (Inter Access Point Protocol) is still in draft version, most of the vendors use proprietary protocols.

WiMax (802.16) L2 Handovers

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- Very similar to WLAN Handovers
- With the important distinction that the AP can explicitly require the terminal to switch to a different AP.

UMTS L2 Handover

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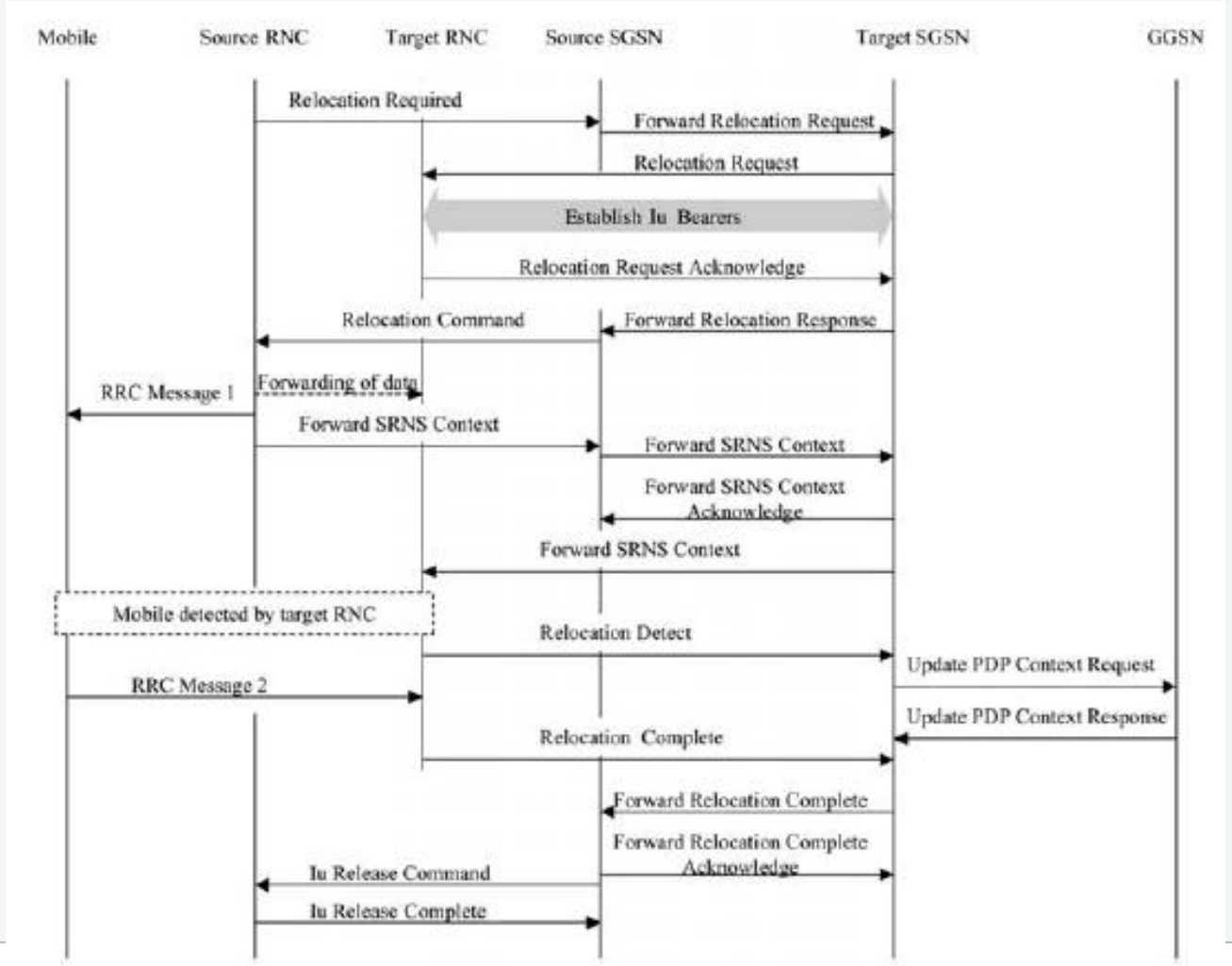

Fig. 4.50 *3GPP PS Domain hard handoff*

UMTS L2 Handover

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- Again it is important to note down that the handover is initiated at the network side.

Layer 3 Handovers

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- MIPv4,
- MIPv6,
- Extensions of MIP,
- Host Based Routing Protocols (HAWAII, CELLULAR IP).

MIP

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- MIP for both versions is a hybrid mode mobile terminal data delivery protocol.
- Home Agent (HA) is the name of the mobility anchor point.
- When a mobile node is in the same IP sub-network as HA (named the Home Network), everything works in standard IP fashion.
- The IP address of the node in home is called the HomeAdress HoA.
- MIP software running on the node and HA makes sure that the user is always reachable over his HoA:
  - The applications on the MN and CN always see HoA

MIP

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- When the mobile node leaves home here is the procedure of events:
  1. MIP Software on mobile node must find out that it is in a new network (movement detection),
  2. Obtain a new IP address from this new network, called the Care-of-Address (CoA),
  3. Send an update to the HoA about the new location,
  4. HA acknowledges the update.

MIP

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- This way all the incoming traffic will be routed to new CoA.
- MIP software on the client is responsible for replacing CoA with HoA in the destination fields of incoming packets.
- MIP software on the client is responsible for replacing HoA with CoA in the source fields of outgoing packets.

MIPv4 vs MIPv6

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- In MIPv4 there is an entity called Foreign Agent (FA) responsible for helping the mobile nodes with :
  - Movement Detection – FA sends periodic advertisements,
  - Obtaining IP Addresses.
- In IPv6 there is built-in neighborhood detection scheme, based on router advertisements.
  - Automatic movement detection,
  - Automatic CoA generation,
  - So in MIPv6 there are no FAs.
- Also in MIPv6 all the messages are encapsulated in IPsec.

MIP Extensions

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- Handover times currently are not good enough to support time critical applications like VoIP.
- There are many flavors to MIP such as
  - FMIP: Start L3 handover as soon as L2 handover starts.
  - HMIP: Delegate home agents which are closer to minimize update delay.
  - Proxy MIP: Relocate MIP functionality to proxies on the access points to minimize the use of air interface

Host Based Protocols

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- Normal IP routing is prefix based.
- When a mobile moves into a new network, the prefix changes and it should obtain a new IP address.
- For operator owned private networks one can use host based routers, and the IP addresses never change.
- Examples to these protocols are Handoff Aware Wireless Access Internet Infrastructure (HAWAII) and Cellular IP.
- However this modification of the routers is expensive, therefore this is not welcomed.

Network Controlled Mobility

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- All of these methods so far were host based.
- We believe this is not a good solution:
  - Air interface is not cheap, and slow
  - Modifications to user equipment is always slow
  - In order to trust the mobile users we have to add security protocols which makes the handovers even slower.

SCALENET

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- That’s why we participated in project ScaleNet.
- Network based Intelligent Mobility and Resource Management in Heterogeneous Operator Networks

Project Description

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- Intelligence:
  1. Through policies that can be entered by the network operator. Policies are basic “condition/action” pairs that can change the response of the whole system.

     Condition: The signal strength on the current interface is less then on the other available interfaces

     Action: Switch the data traffic to the interface with the best signal strength
  2. Context aware. Additional information is collected from the user equipment and network nodes (Node B’s, Meters, AAA servers) to be used as conditions in the policies.

Project Description

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- Network based Intelligent Mobility and Resource Management in Heterogeneous Operator Networks
  - Mobility: Current mobility schemes are user based. Network operator has to have a say in the mobility decisions as it is closely coupled with (especially wireless) resource allocation.

Project Description

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- Resource Management: 3G networks have strict mechanisms for resource management, where as WLAN and WIMAX are not that stringent on resource management.
- Inform or order when it is allowed the resource management entities in coupling with mobility decisions.

Project Description

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- Network based Intelligent Mobility and Resource Management in Heterogeneous Operator Networks
  - Heterogeneous Operator Networks: We concentrate on networks concentrating on access networks of different technologies sharing a common core network all owned by a single operator.

On-the-fly-policy GUI

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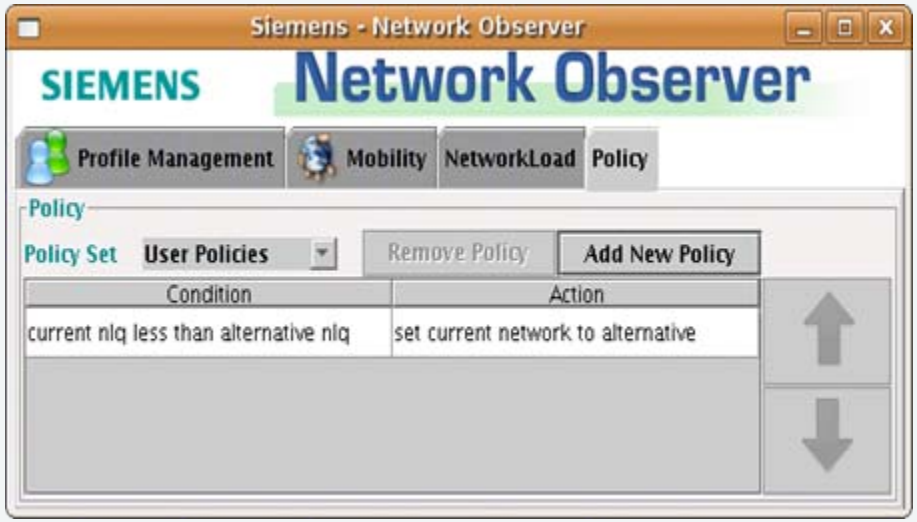
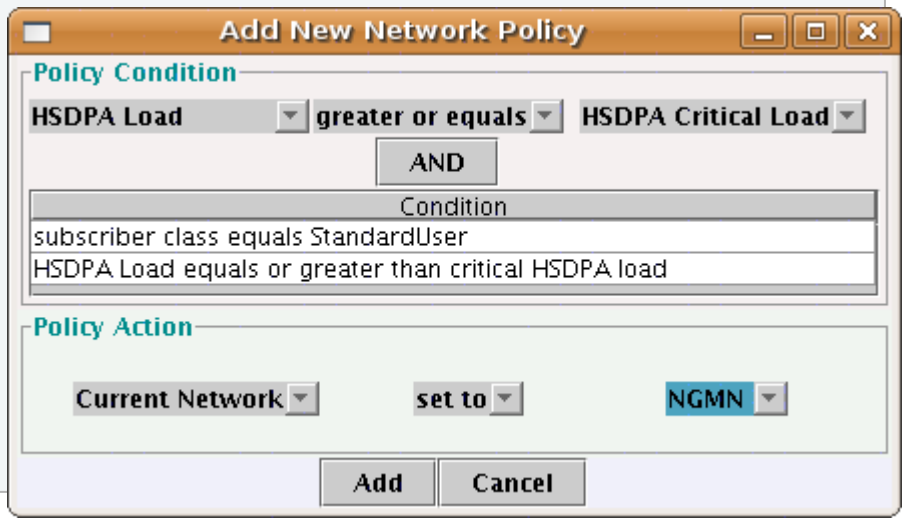
- How is it done now?





On-the-fly-policy GUI policy GUI

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- Arbitrary combination of conditions based on:
  - NLQ, Network Load, Bandwidth, Subscriber Class, Available Networks, User Name.
- Relevant actions are presented to the user of the GUI, including choosing access technology, allocation bandwidth
- The policies are compiled and loaded on to the system on the real-time
- Conflicts are resolved on a priority basis, which is also dynamically adjustable

Achievements: Distributed NAMM

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- The server/client architecture of NAMM is not scalable, we believe (and hope to prove) placing multiple NAMMs on the network, connecting them with an overlay network and sharing the load of evaluating policies between them will yield a more scalable solution.

Achievements: Distributed NAMM

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- Our solution:
  - Pastry is an p2p overlay network implementation of a Distributed Hash Table. We are using an open source version Free-Pastry.
  - On top of Pastry we use the open source SCRIBE tool, which builds multicast-tree's for subscribe/publish type of services.

Achievements: Distributed NAMM

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- Our Solution (continued)
  - We use the anycast functionality to implement the LaLa (Location Aware Load Aware Overlay Anycast) algorithm.
  - By modifying the Load metric in LaLa algorithm to suit the NAMM computation load, we are able to find a NAMM which is a member of a Scribe group in LALA fashion.

Open Issues

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- Extending policies with Goals und Plans
  - New structure: Condition ➔ GOAL instead of Condition ➔ Action
  - Goals are accomplished by agent plans, with which high level policies are decomposed of chain of low level plans.

Future

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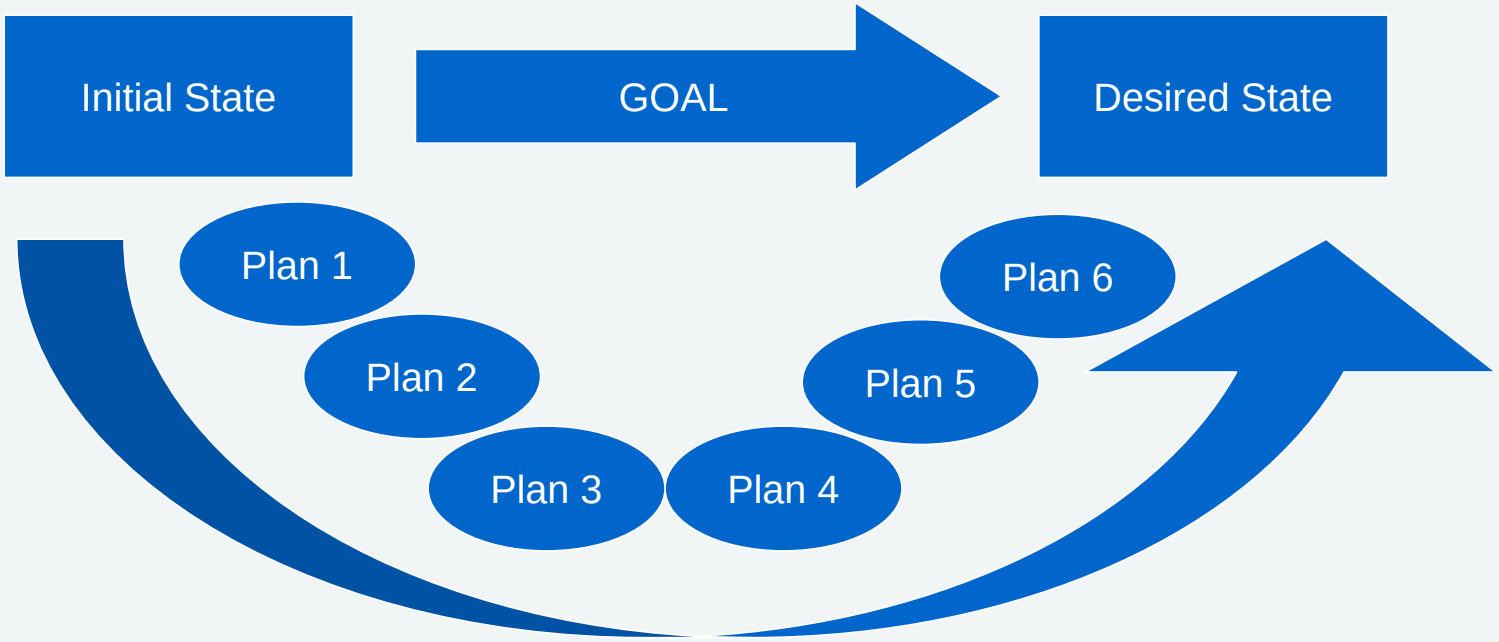

Network Controlled Mobility

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- We have a different question to be answered now, once we decide to control the mobility of the users from the network side.
- Given that we have Layer 2 and Layer 3 mechanisms with which we can move users and their services between different access technologies, what is the best way of distributing the users?

CRRM

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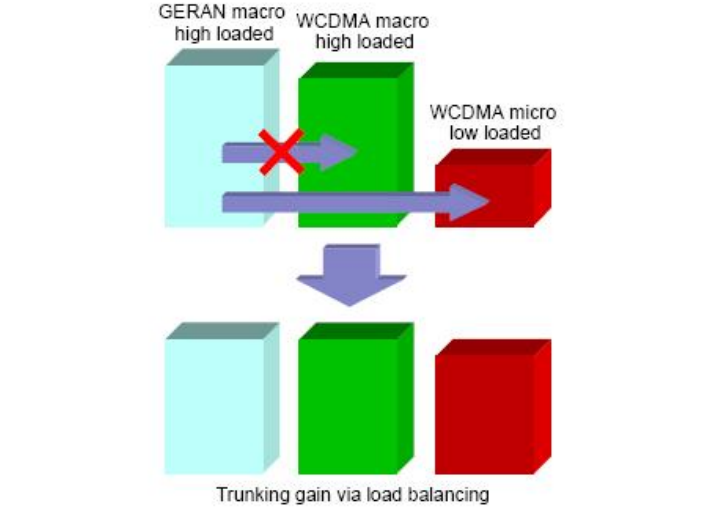
- This is called the Common Radio Resource Management (CRRM).
- Trunking gain:



Trunking gain via load balancing

Benefits of CRRM

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- Achieved through:
  - directing a real-time user to another system by:
    - inter system handover (IS-HO),
    - directed retry (DR) if the loading is high - resulting in less blocking.
  - directing a non-real-time user to another system by inter-system network controlled cell reselection (IS-NCCRS)
    - if the cell throughput is below threshold (high delay) – resulting in a higher average throughput (smaller average delay).

Benefits of CRRM

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- Recently it was shown that additional gains can be achieved if the users services are allocated to access technologies that are more suitable for them.
- Capacity can be defined as the maximum number of users that can be supported in a system while a minimum level of quality is guaranteed.

Optimum CRRM

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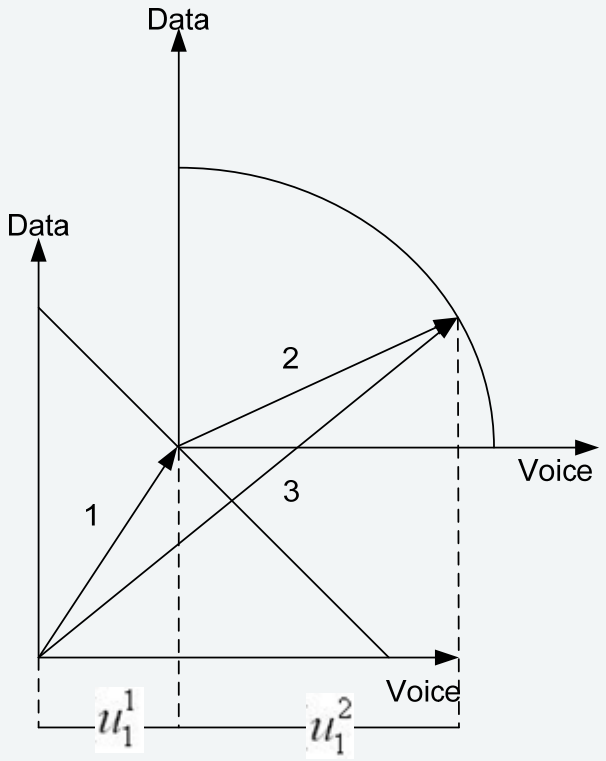
- The optimum CRRM problem is:
  - What is the optimum distribution of services onto different access networks, that maximize the combined capacity.
- It can be visualized graphically employing combined service capacity regions of different systems.

Optimum CRRM



Optimum CRRM

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- Refer to this document

Microsoft Word Document

- It turns out that services should be mixed on subsystems makes sense only if the subsystems are equally good at carrying services.
- In the case of linear capacity regions for both system, the system with a less negative slope should be loaded with as many possible voice users as possible, and service should be mixed on the other one.

Optimum CRRM

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- In the case of at least one convex capacity region, points where the slopes match can be found, thus service can be mixed on both of the subsystems.
- When there is at least one concave capacity region, those equal slope points correspond to local minimums, thus just like the linear case, service is mixed in one of the systems, while the other caries one of the services.

Optimum CRRM

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- The algorithms based on this principle require calculations to be made every time a new user comes in,
  - Hence not suitable for dynamic environments like the heterogeneous networks.
- There are approximations that are implemented by more dynamic algorithms.

CRRM as Bin-Packaging

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- Another approach is to formulate the CRRM problem as a bin packaging problem, and use the well known approximations.
- The classical bin packing problem can be formulated as fitting *n* objects of sizes $a_1 \ldots a_n$ in unit-sized bins, while minimizing the number of bins used.

CRRM as Bin-Packaging

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- In the *online* problem objects come one by one, and only the size of the current object to be assigned is known.
- The number of bins available at any time may be bounded, which makes the problem *bounded*.
- Relaxing the equal unit sized bin condition we get the *variable-sized bounded online bin packaging problem* as the formulation matching the multi service multi access selection problem

CRRM as Bin-Packaging

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- **First Fit:** A subsystem is chosen randomly. If no free capacity is available in the chosen subsystem the other systems are chosen one by one in a round robin fashion. If there is no subsystem with free capacity, the application is rejected.
- **Best Fit:** In this algorithm capacities of all the subsystems are checked, and the application is allocated to the one with the least remaining amount of free capacity.

CRRM as Bin-Packaging

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- **Worst Fit:** In this algorithm capacities of all the subsystems are checked, and the application is allocated to the one with the most remaining amount of free capacity
- **Less Voice:** This is an algorithm that follows the proposition of the optimal CRRM and separates voice from other services as much as possible.

- Non Elastic Applications:

Algorithm	***Blocking Probability***
Less Voice	%11
Best Fit	%12
First Fit	%13
Worst Fit	%15
Random	%17

- Elastic Applications:

Algorithm	***Blocking Probaility***
Less Voice	%4
Worst Fit	%4
First Fit	%6
Best Fit	%6
Random	%11

CRRM

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- From a network operator point of view, separating services is the optimum solution.

Ending Remarks

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- We are always interested in getting students for
  - Projects
  - Internships
  - Diplomarbeit
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