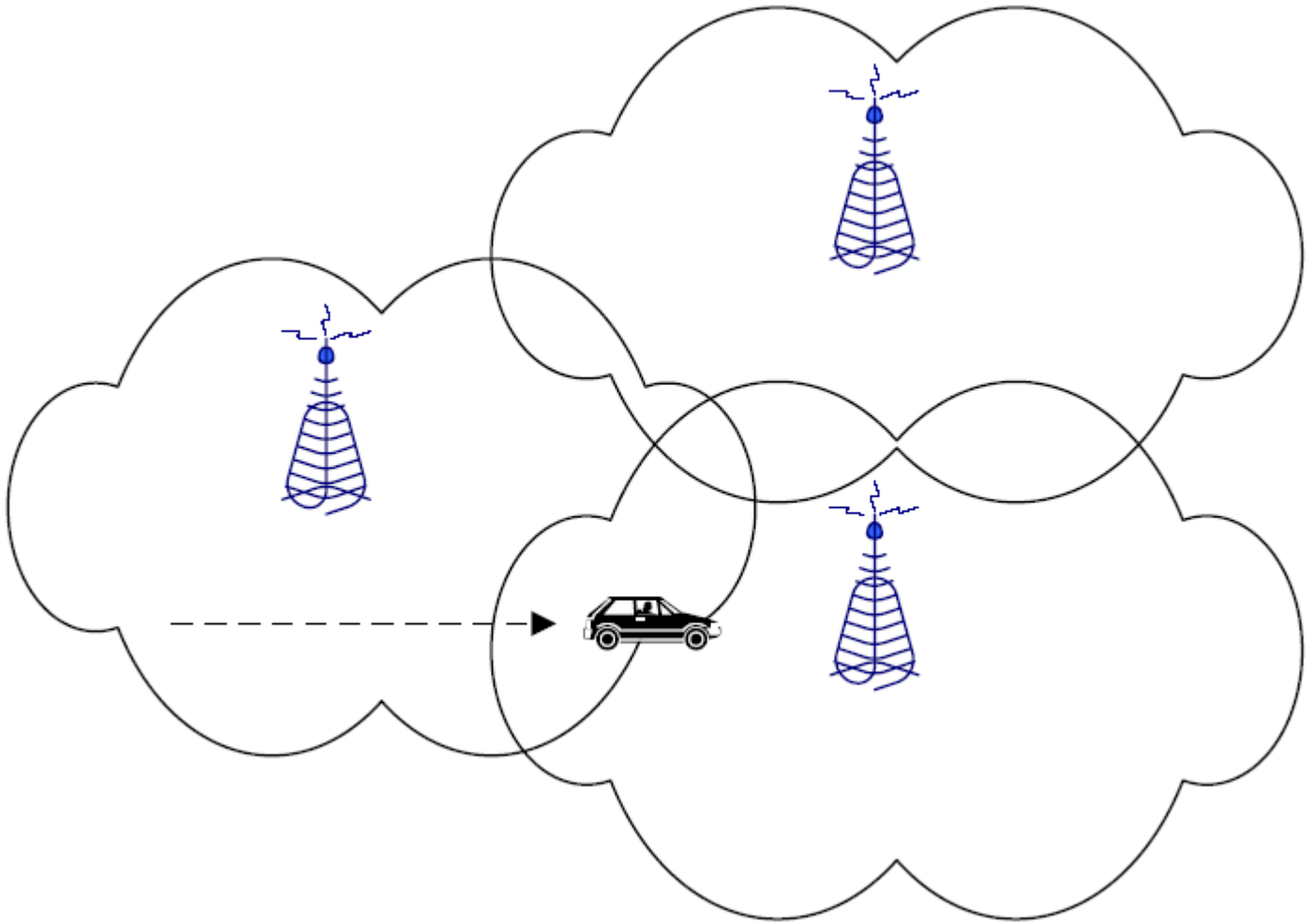
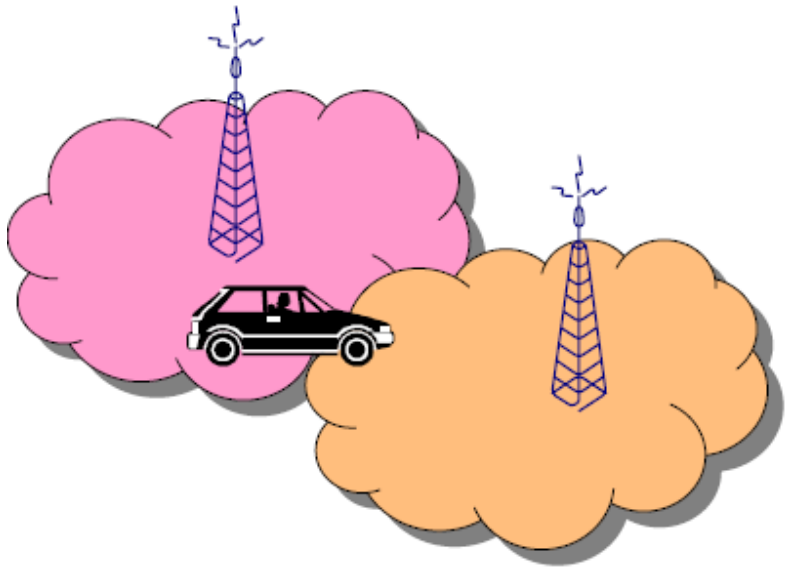
Handoff Management

Handoff



BS Coverage Area

- BS coverage area: irregular
- In the cell boundary
  - Signal from a neighboring BS ⬆
  - Signal from the serving BS ⬇
- Otherwise: Forced termination



Issues for Handoff Management

- Handoff detection
  - Who and how
- Channel assignment
- Radio link transfer

Handoff Detection

- Handoff detection:
  - Who initiates the handoff process?
  - How is the need for handoff detected?
- Handoffs are expensive.
- Overlap of adjacent coverage area is desired
- Handoff criteria
  - If not chosen appropriately, then the call might be handed back and forth several times between two adjacent BSs
  - If too conservative, then the call may be lost before the handoff
- Unreliable and inefficient handoff procedures will reduce the quality and reliability of the system

Link Measurement

- Handoff detection is based on link measurement.
- Signal measurements used to determine the quality of a channel:
  - WEI (Word Error Indicator)
    - Metric that indicates whether the current burst was demodulated properly in the MS
  - RSSI (Received Signal Strength Indication)
  - QI (Quality Indicator)
    - Signal to interference and noise (S/I) ratio
- To make the handoff decision accurately and quickly, it is desirable to use both WEI (over a period of time) and RSSI (instantaneously)
- RSSI measurements are affected by Fading

Fading

- Distance-dependant Fading or Path Loss
  - Occurs when the received signal becomes weaker due to increasing distance between MS and BS
- Lognormal Fading or Shadow Fading
  - Occurs when there are physical obstacles (e.g. hills, towers, and buildings) between the BS and MS, which can decrease the received signal strength
- Rayleigh Fading or Multipath Fading
  - Occurs when two or more transmission paths exist between MS and BS
  - Two types of Multipath Fading
    - Rayleigh Fading: when obstacles are close to the receiving antenna
    - Time Dispersion: when the object is far away from the receiving antenna

Handoff Detection

- Ideally, the Handoff decision should be based on distance-dependent fading and, to some extent, on shadow fading
- Handoff decision is independent of Rayleigh Fading
- This can be accomplished by averaging the received signal strength for a sufficient time period

Channel Comparison

- MS must also measure or sample all frequencies in the band of interest to find suitable handoff candidate
- Channel comparisons for handoff are based on RSSI and QI metrics
- Since multipath environment tends to make the RSSI and QI metric vary widely in the short term
- Since it is preferable not to perform handoff to mitigate brief multipath fades
- Such handoff could cause unnecessary load on the network
- Hence the MS should average or filter these measurements before using them to make decision

Channel Comparison

- Handoff should be initiated whenever the channel has the best filtered RSSI exceeding that of the current channel.
- Filtering process applied to the RSSI and QI metrics will reduce their usefullness in mitigating sudden “shadow” fades, such as when rounding a corner or closing a door.
- The downlink WEI can be used to detect and correct these trouble situations on an “override” basis.
- C_{down}: number of downlink word errors that is reset by every complete measurement cycle
- If C_{down} exceeds some threshold, the MS should initiate a handoff when an appropriate channel can be found

Dwell Timer

- To reduce the potential tendency of an MS to request a large number of handoffs in quick succession
- This timer prevents the MS from requesting another handoff until some reasonable period of time after a successful handoff.
- Adaptive measurement interval for handoffs:
  - Uses Dopler frequency to estimate the velocity of the vehicle
  - Then averaging measurement interval

Handoff detection

- As the MS moves away from one BS toward another, the signals received from the first BS become weaker, and from the second BS become stronger
- This slow effect is often masked by the multipath Rayleigh fading and the lognormal shadow fading
- Short-term Rayleigh fading is handled in mobile system designs by techniques:
  - Diversity techniques such as Frequency hopping, multiple receivers
  - Signal Processing techniques such as bit interleaving, equalizers
- Rayleigh fading is frequency dependent
- Longer-term shadow fading is compensated by increasing transmitter power and the co-channel reuse distance

Strategies for Handoff detection

- Who makes a decision for handoff?
- Three handoff detection schemes:
  - Mobile-controlled handoff (MCHO)
    - MS continuously monitors the signals of the surrounding BSs and initiates handoff process when some criteria are met
  - Network-controlled handoff (NCHO)
    - The surrounding BSs measure the signal from the MS, and the network initiates the handoff process when some criteria are met
  - Mobile-assisted handoff (MAHO)
    - The network asks the MS to measure the signal from the surrounding BSs. The network makes the handoff decision based on reports from the MS
- Advanced mobile systems follow MAHO

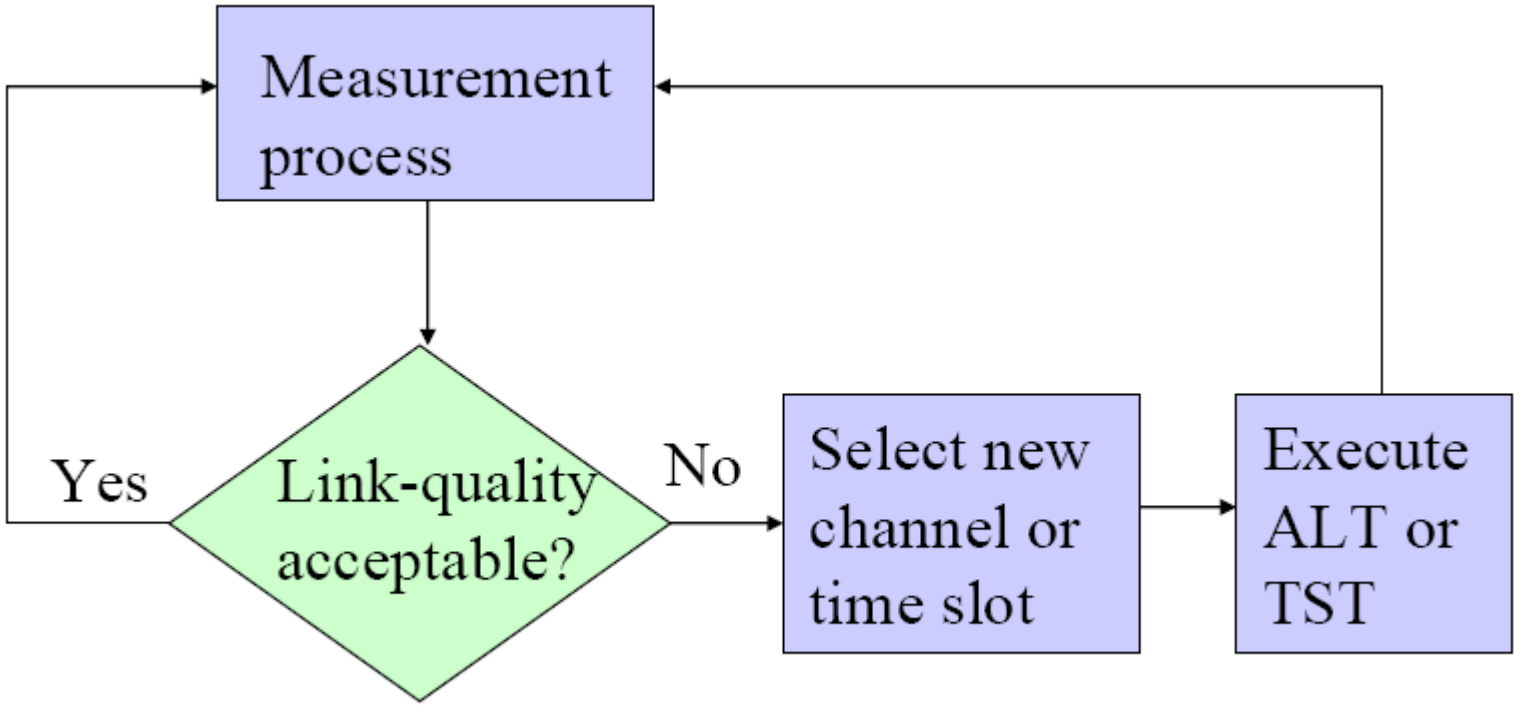
Mobile-Controlled Handoff (MCHO)

- Popular for low-tier radio systems
- MS continuously monitors the signal strength and quality from the accessed BS and several handoff candidate BSs
- When some handoff criteria are met, the MS checks the best candidate BS for an available traffic channel and launches a handoff request
- Two common handoffs:
  - automatic link transfer (ALT) - transfer between two base stations
  - time slot transfer (TST) - transfer between channels of a single BS

Mobile-Controlled Handoff (MCHO)

- Automatic link transfer control requires the MS to make quality measurements of the current and candidate channels in the surrounding BSs.
- The MS's handoff control between channels on the same BS is made possible by passing uplink-quality information, in the form of word-error indicator, back to the MS on the downlink
- As a part of the demodulation process, the MS obtains two pieces of information: RSSI and QI

Mobile-Controlled Handoff (MCHO)



MS-quality maintenance processing

Network-Controlled Handoff (NCHO)

- Used by low-tier CT-2 plus and by high-tier AMPS
- BS monitors the signal strength and quality from the MS
- When deteriorate below some threshold, the network arranges for a handoff to another BS
- The network asks all surrounding BSs to monitor the signal from the MS and the measurement results back to the network
- The network then chooses a new BS for the handoff and informs both the MS (through old BS) and the new BS

Network-Controlled Handoff (NCHO)

- Network uses multiple (current and surrounding) BSs to supervise the quality of all current connections by making measurements of RSSI
- MSC will command surrounding BSs to occasionally make measurements of these links
- MSC makes the decision when and where to effect the handoff
- Heavy network signaling traffic and limited radio resources at BSs prevent frequent measurements of neighboring links $\Rightarrow$ long handoff times
- Handoff time: upto 10sec or more

Mobile-Assisted Handoff (MAHO)

- Used in GSM, IS-136 and IS-95
- The network asks the MS to measure the signal from the surrounding BSs and report back to old BS
- The network makes the handoff decision based on the reports from the MS.
- Handoff process is more decentralized
- The MS and the BS supervise the quality of the link, RSSI and WEI values
- In GSM the MS transmits measurements twice a second
- GSM handoff execution time ~ 1sec
- In both NCHO and MAHO - if the network can't tell the mobile about the new channel/time slot/… to use before the link quality has decayed too far, the call may be terminated

Handoff Failures

- No channel on selected BS
- Insufficient resources as determined by the network (for example, no available bridge, no suitable channel card {for example, none supporting the voice CODEC or radio link coding}
- It takes too long for the network to set up the new link
- Target link fails during handoff

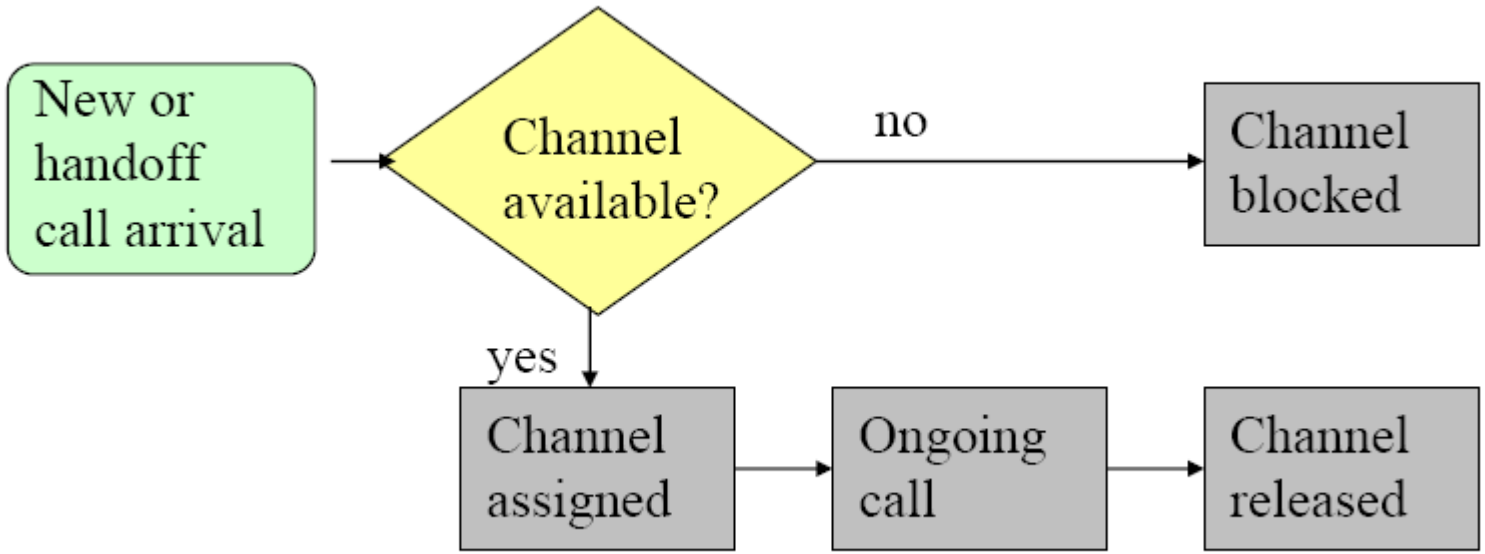
Channel Assignment

- Goals:
  - to achieve a high degree of spectrum utilization for a given grade of service
  - use a simple algorithm
  - require a minimum number of database lookups
- Unfortunately it is hard to do all of these at once!
- If there is no available channel, then
  - new calls are blocked
  - existing calls that can't be handed over $\Rightarrow$ forced terminations

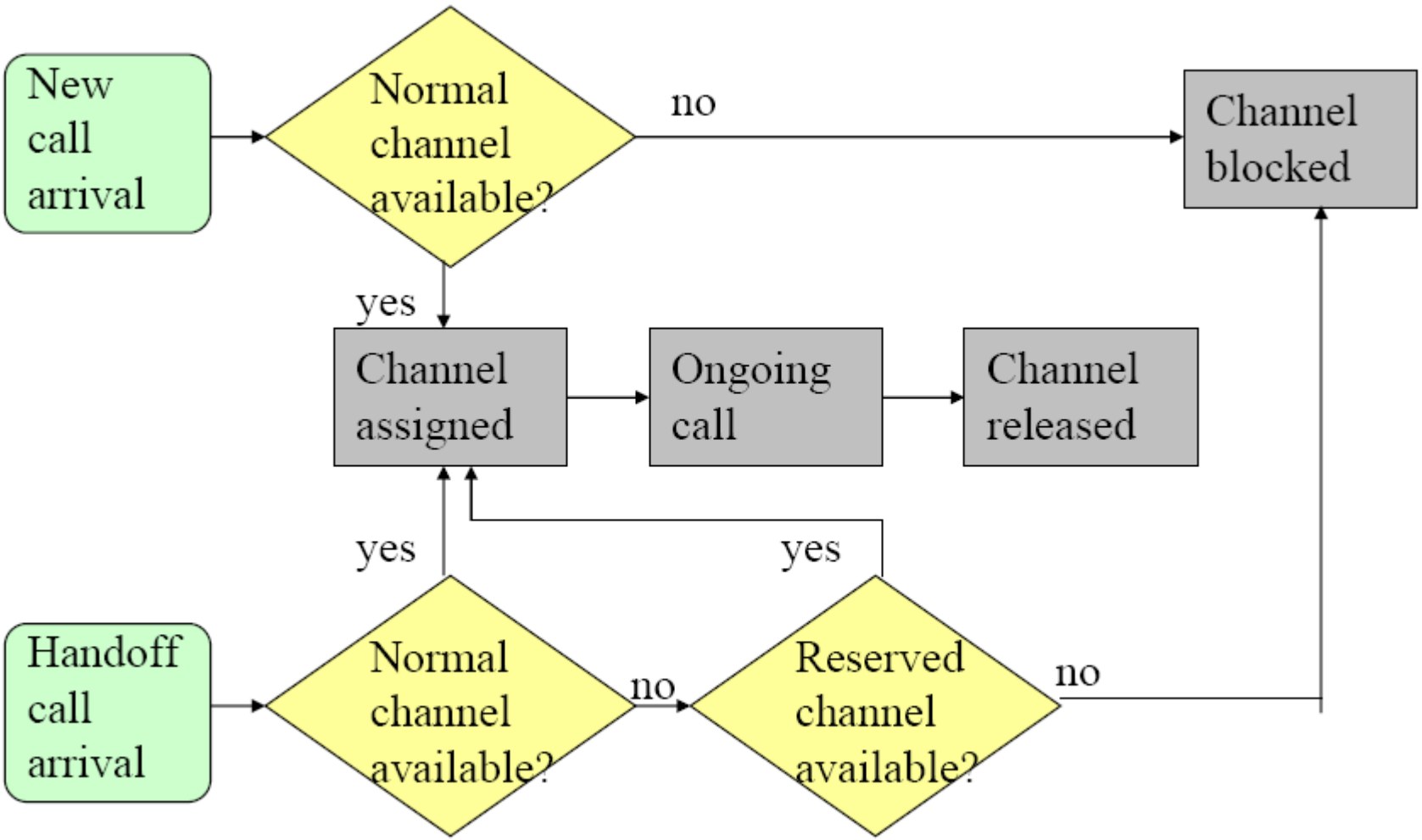
Channel Assignment Strategies

- Schemes introduced to reduce the number of forced terminations, at the cost of increased block or decreased efficiency:
  - Nonprioritized scheme (NPS) - handoff call treated the same as a new call
  - Reserved Channel scheme (RCS)- reserves some resources for handoffs
  - Queuing Priority scheme (QPS) - exploit the over lap (handoff area)
  - Subrating scheme (SRS) - switching codes of one or more calls to free resources

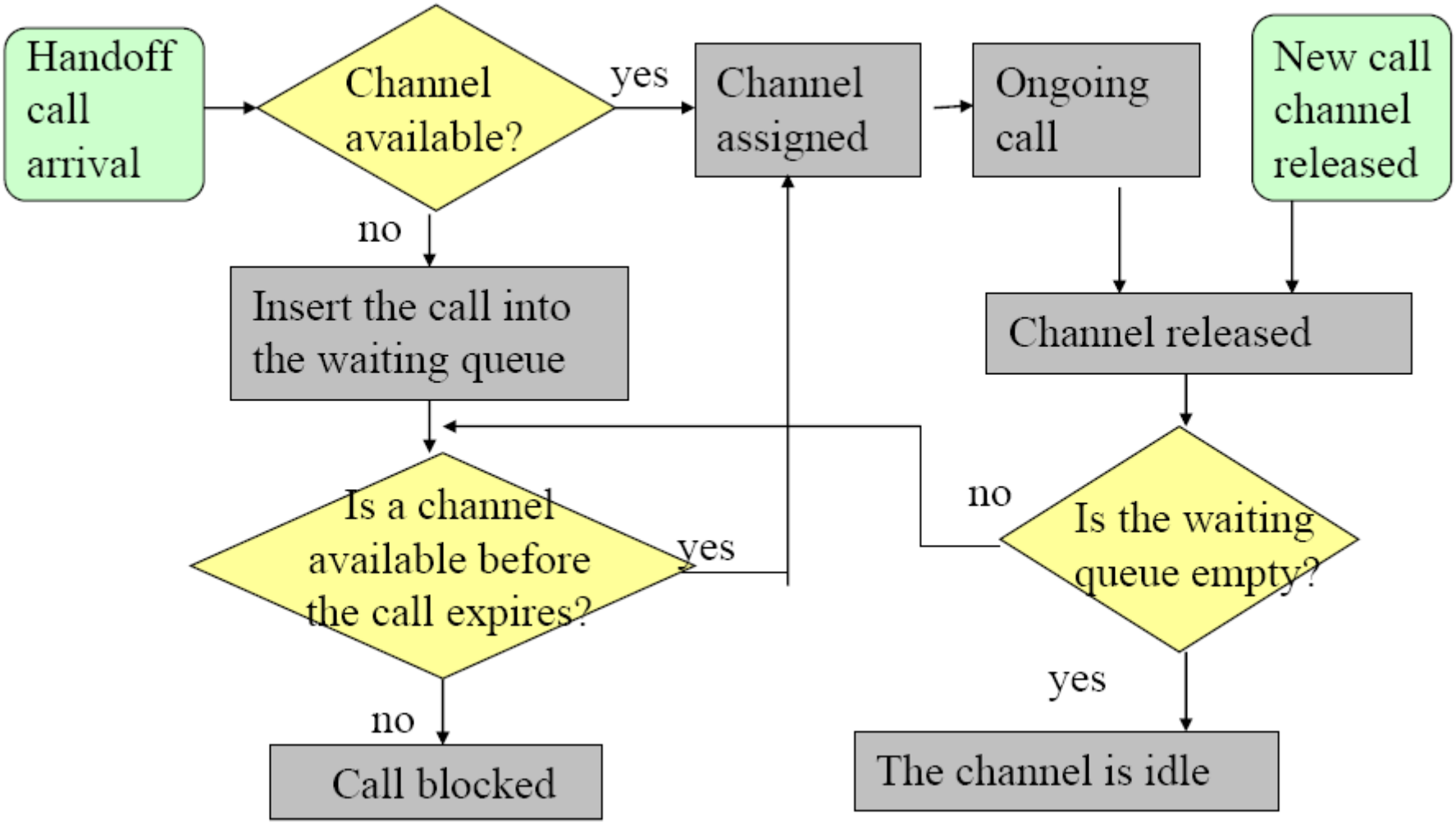
Flowchart for Non-prioritized Scheme



Flowchart for Reserved Channel Scheme



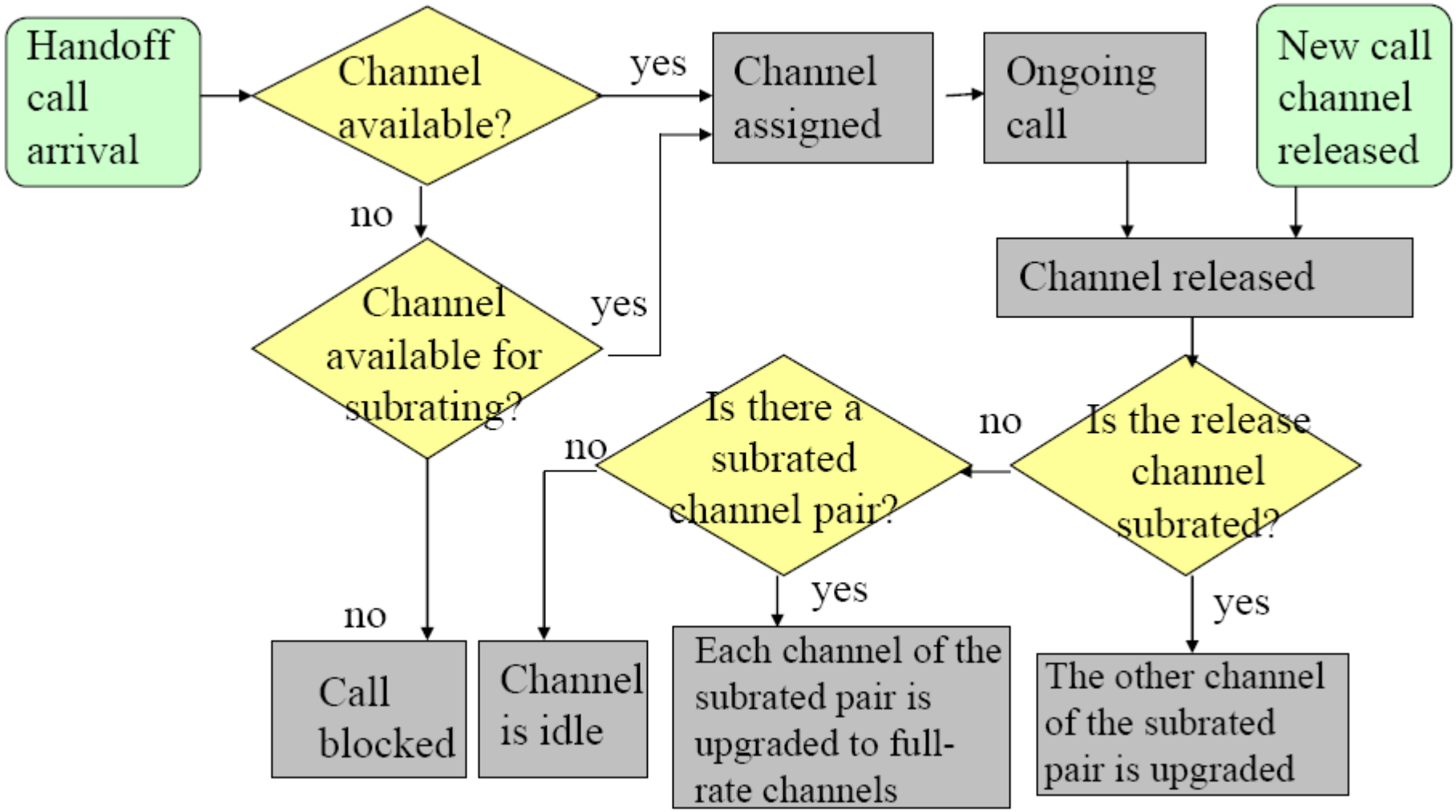
Flowchart for Queuing Priority Scheme (for Handoff Calls)



Queuing Priority Scheme (for Handoff Calls)

- Scheduling policies for the QPS waiting queue:
  - FIFO
  - Measured-based priority scheme (MBPS)
    - A nonpreemptive dynamic priority policy
    - Priorities are defined by the power level that the MS receives from the BS of the new cell

Flowchart for Subrating Scheme (for Handoff Calls)



Implementation Issues

- RCS is easy to implement
- It reduces the forced termination probability more effectively than NPS
- New call-blocking probability for RCS is larger than that of NPS
- RCS is desirable when reducing forced termination is much more important than reducing new call blocking

Implementation Issues

- Implementation for the measurement-based priority scheme (MBPS) is more complex than that for the FIFO scheme, but performance is identical
- QPS reduce forced terminations, at the expense of increased new call blocking
- Probability of incomplete calls for FIFO and MBPS is slightly lower than that for NPS
- QPS add hardware/software complexity for both BSs and MSs to manage waiting queues

Implementation Issues

- SRS has the least forced termination probability and the probability of incomplete calls when compared with other schemes.
- This benefit is gained at the expense of the extra hardware/software complexity required to subrate a channel.

Implementation Issues: Conclusion

- Trade-off between implementation complexity and performance
- If reducing forced termination is more important than reducing total call incompletion, then RCS, QPS, and SRS are all better than NPS
- If implementation cost is major concern, then RCS and NPS should be considered.
- To achieve the best performance with a slight voice quality degradation, SRS should be selected.
- If BS density is high in a given PCS service area, then QPS may be good choice.

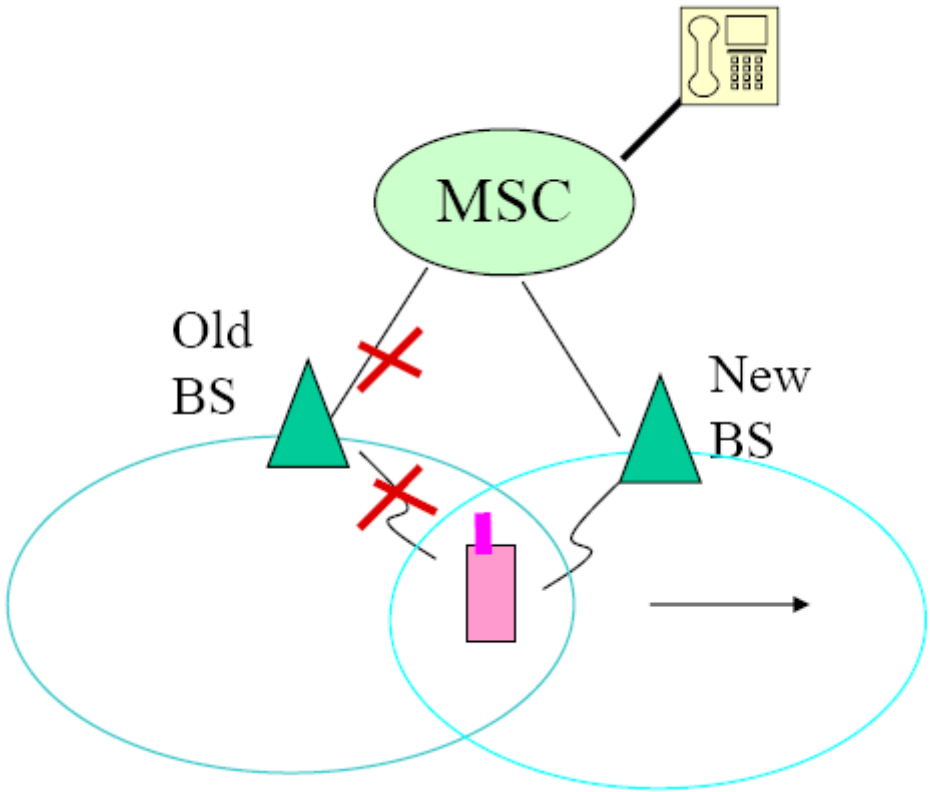
Handoff Management: Radio Link Transfer

Link Transfer Procedure

- Hard Handoff-Oriented
  - MS connects with only one BS at a time
  - Some interruption in the conversation during the link transition
  - Used in TDMA and FDMA systems
- Soft Handoff-Oriented
  - MS receives/transmits the same signal from/to multiple BS simultaneously
- Soft Handoff is more complicated than Hard Handoff

Link Transfer Types

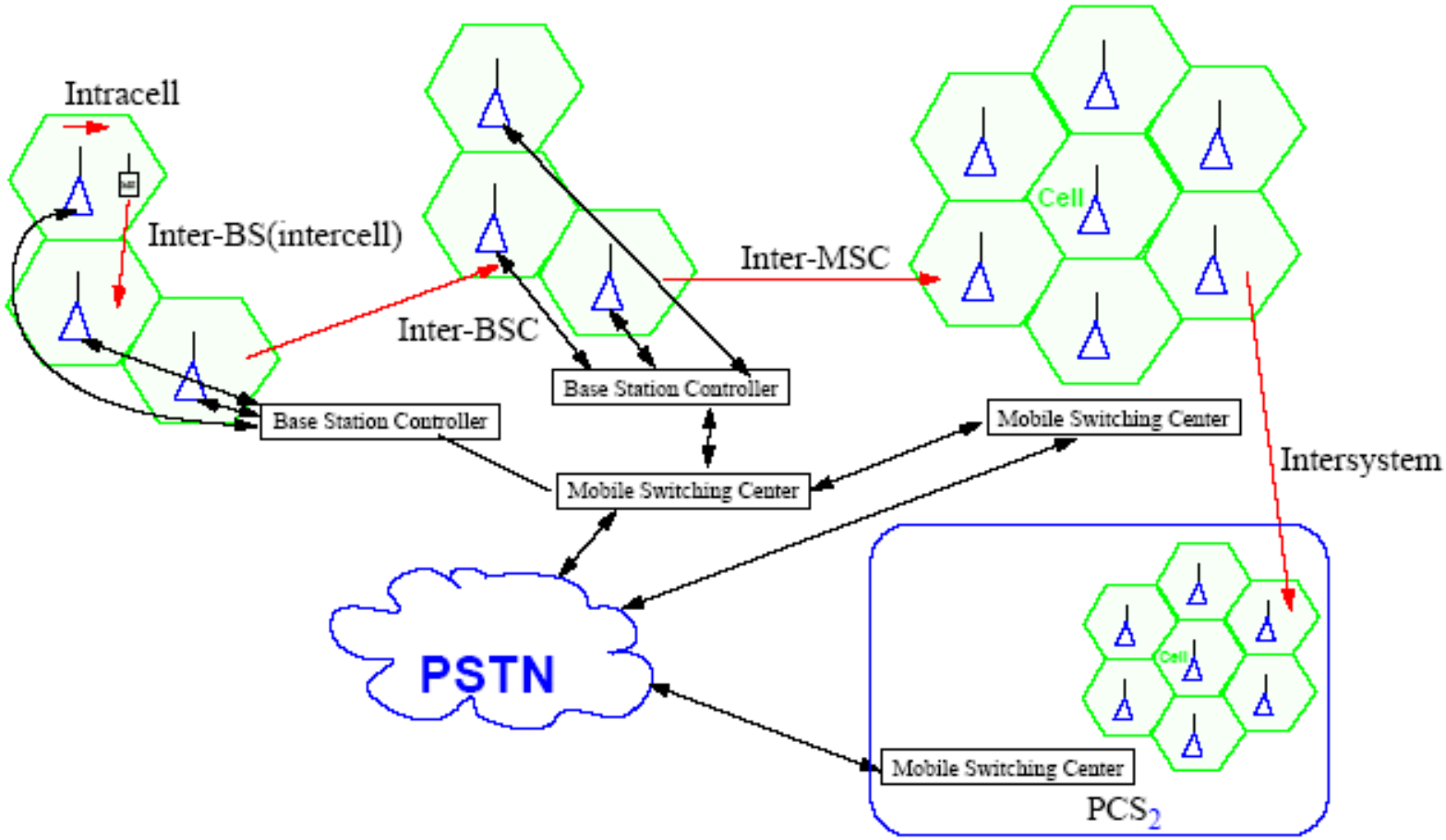
- Two Operations
  - The radio link is transferred from the old BS to the new BS.
  - The network bridges the trunk to the new BS and drop the trunk to the old BS.



Link Transfer Types

- Link transfer cases:
  1. Intracell
     - Link transfer is between two time slots or channels in the same BS
     - In TDMA system, this is referred as Time Slot Transfer (TST)
  2. Intercell or inter-BS
  3. Inter-BSC
  4. Intersystem or inter-MSC
  5. Intersystem between two PCS networks
- Focus on Inter-BS Handoff

Link Transfer Types

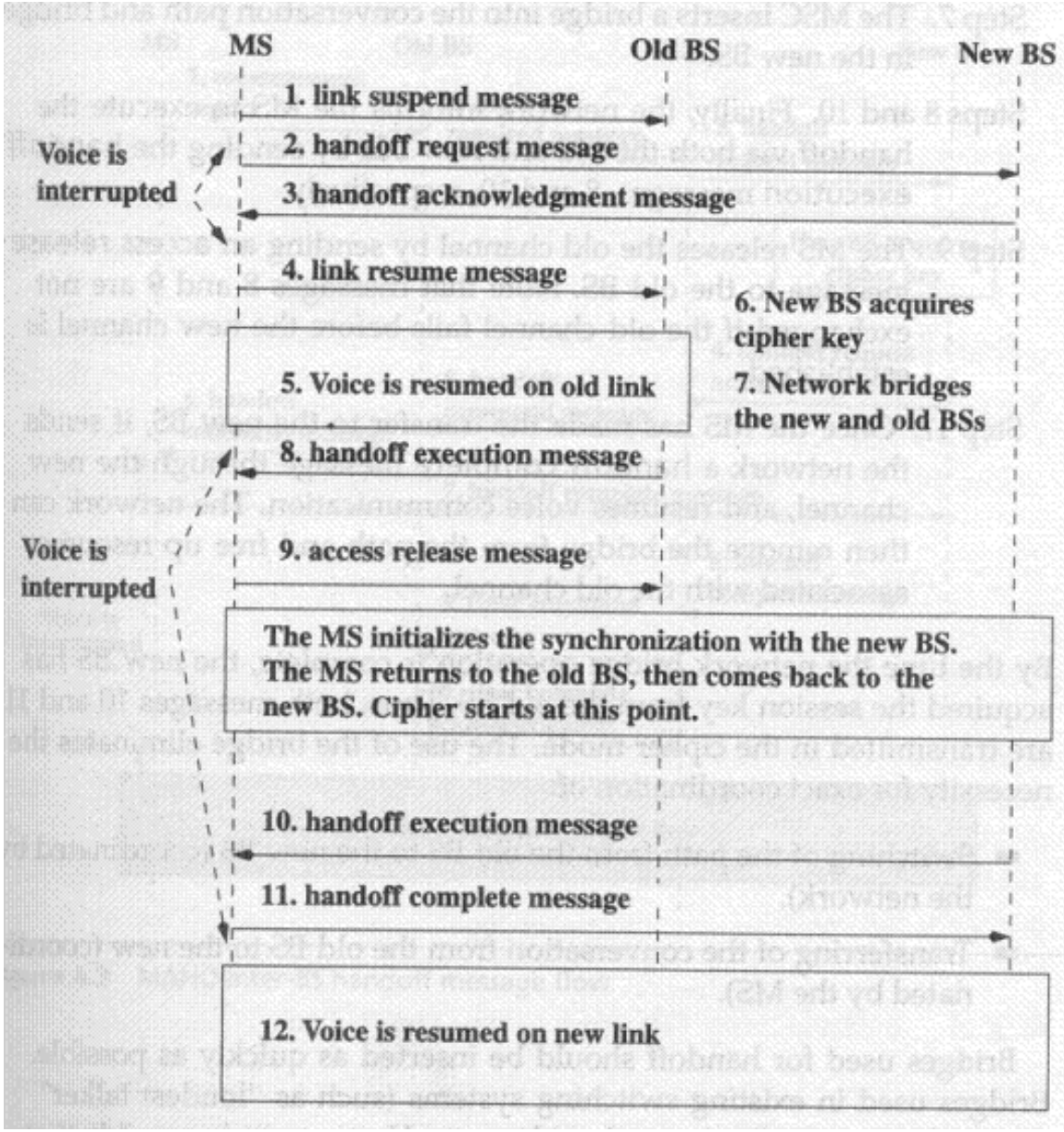


Handoffs, mobile moves within PCS1 and then on to PCS2

Hard Handoff

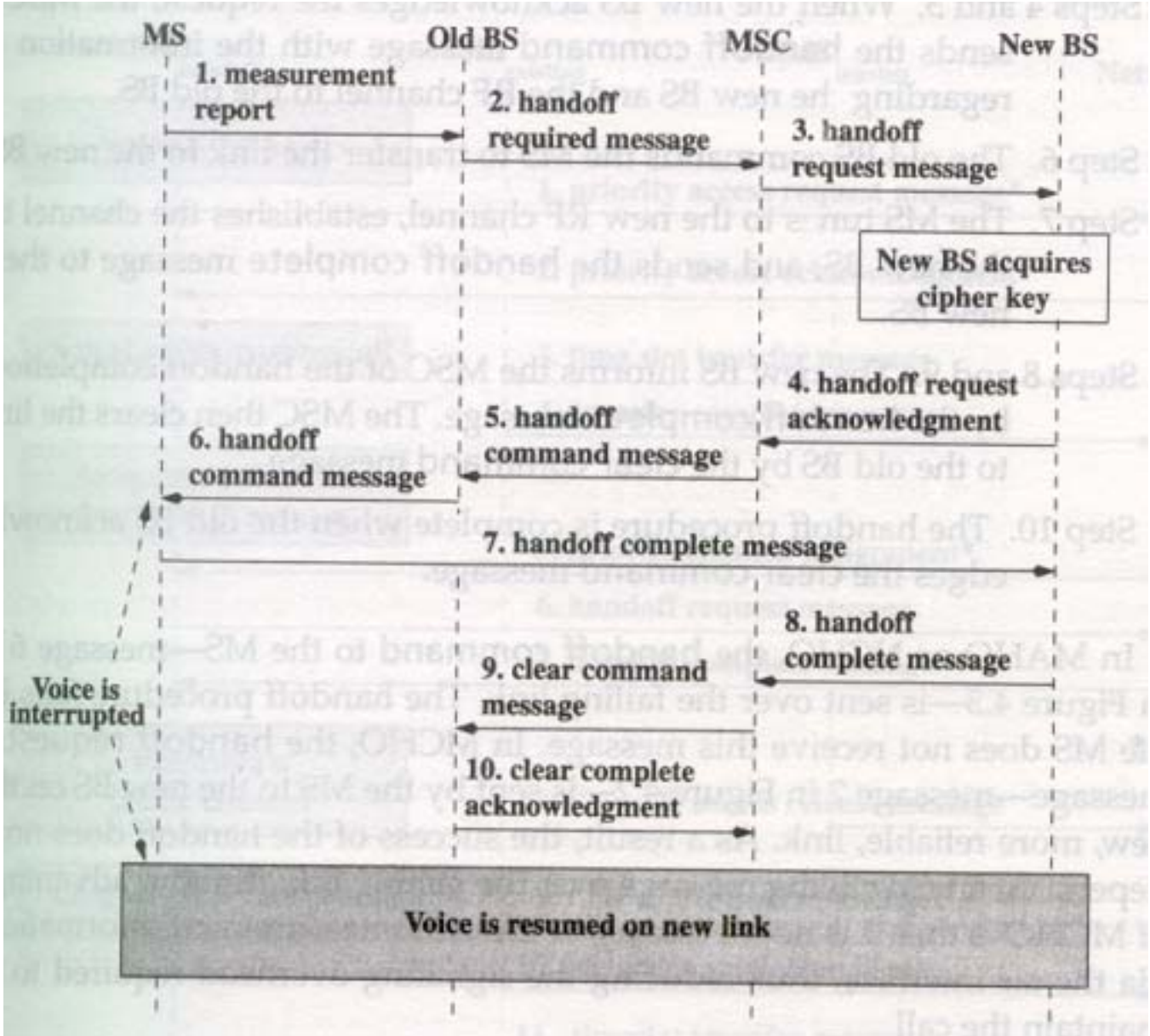
MCHO Link Transfer

- New radio channel is selected by MS
- Handoff request message is transmitted by the MS to the new BS
- MS is responsible to choose the best BS



MCHO Inter-BS handoff message flow

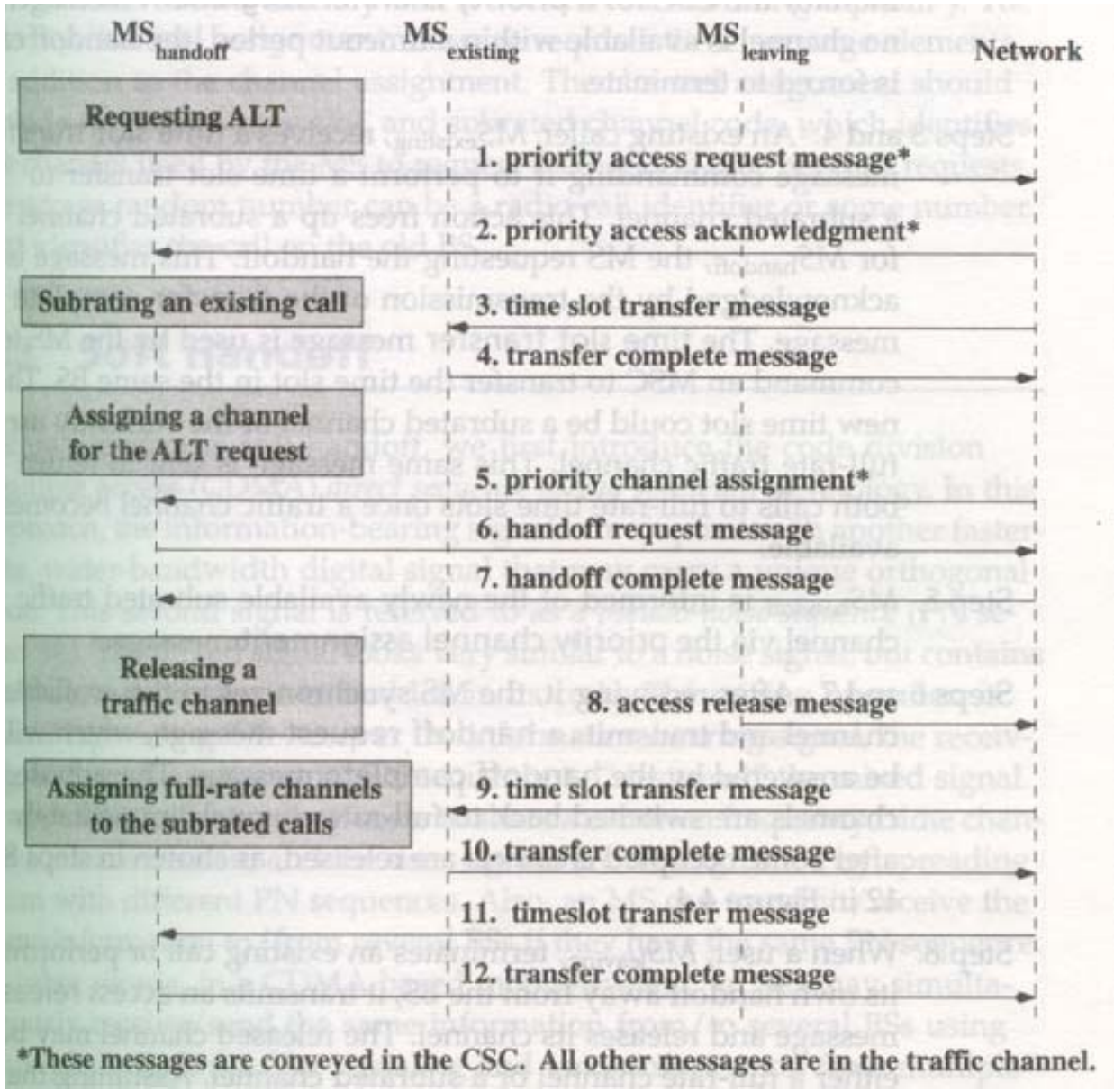
MAHO/NCHO Link Transfer



MAHO Inter-BS handoff message flow

Subrating MCHO Link Transfer

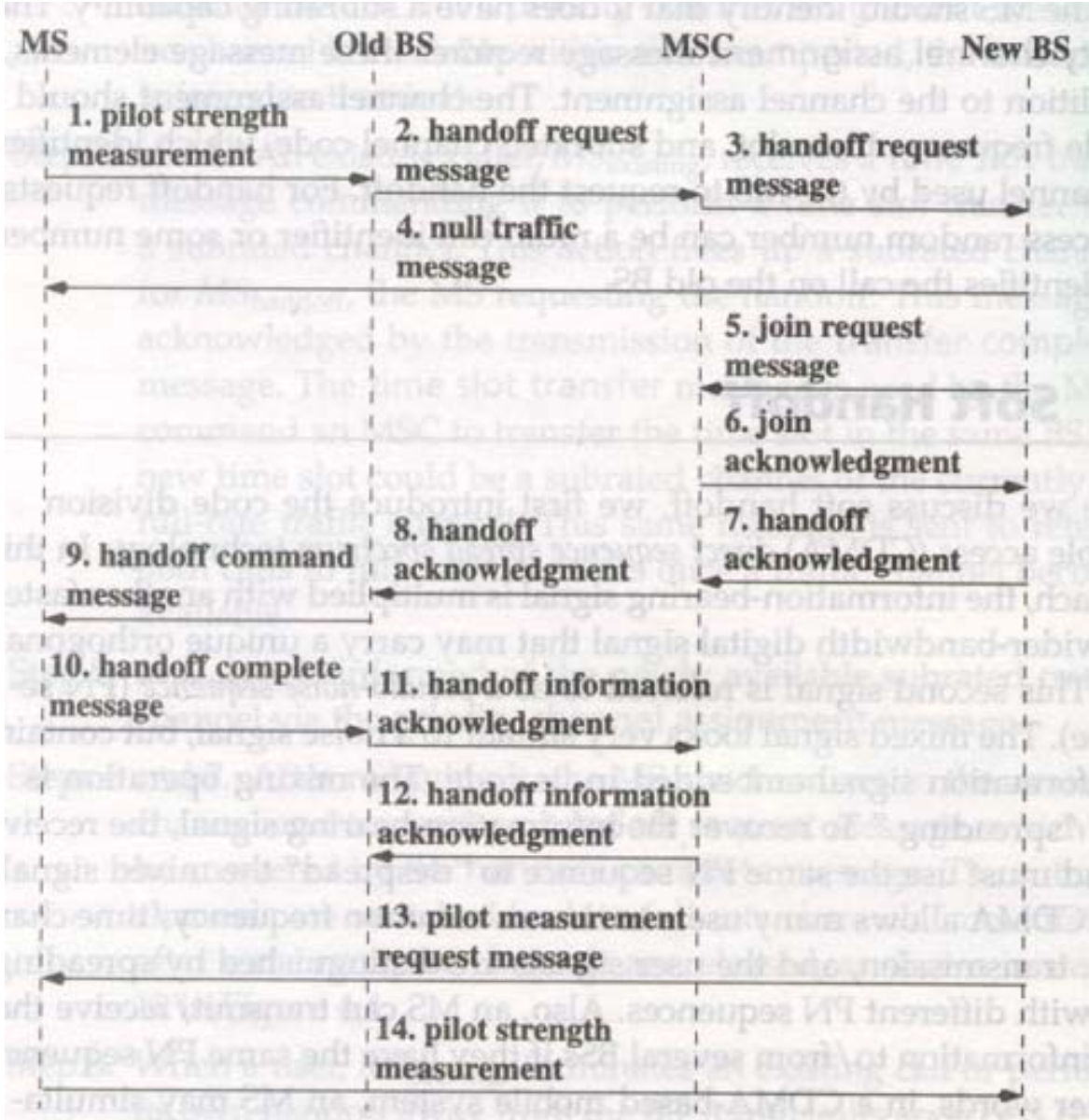
- Procedure of subrating a full-rate channel into subrated channels for handoff request consists of three parts:
  1. Requesting the Handoff
  2. Subrating an existing call
  3. Assigning the newly created subrated channel to the MS requesting the Handoff



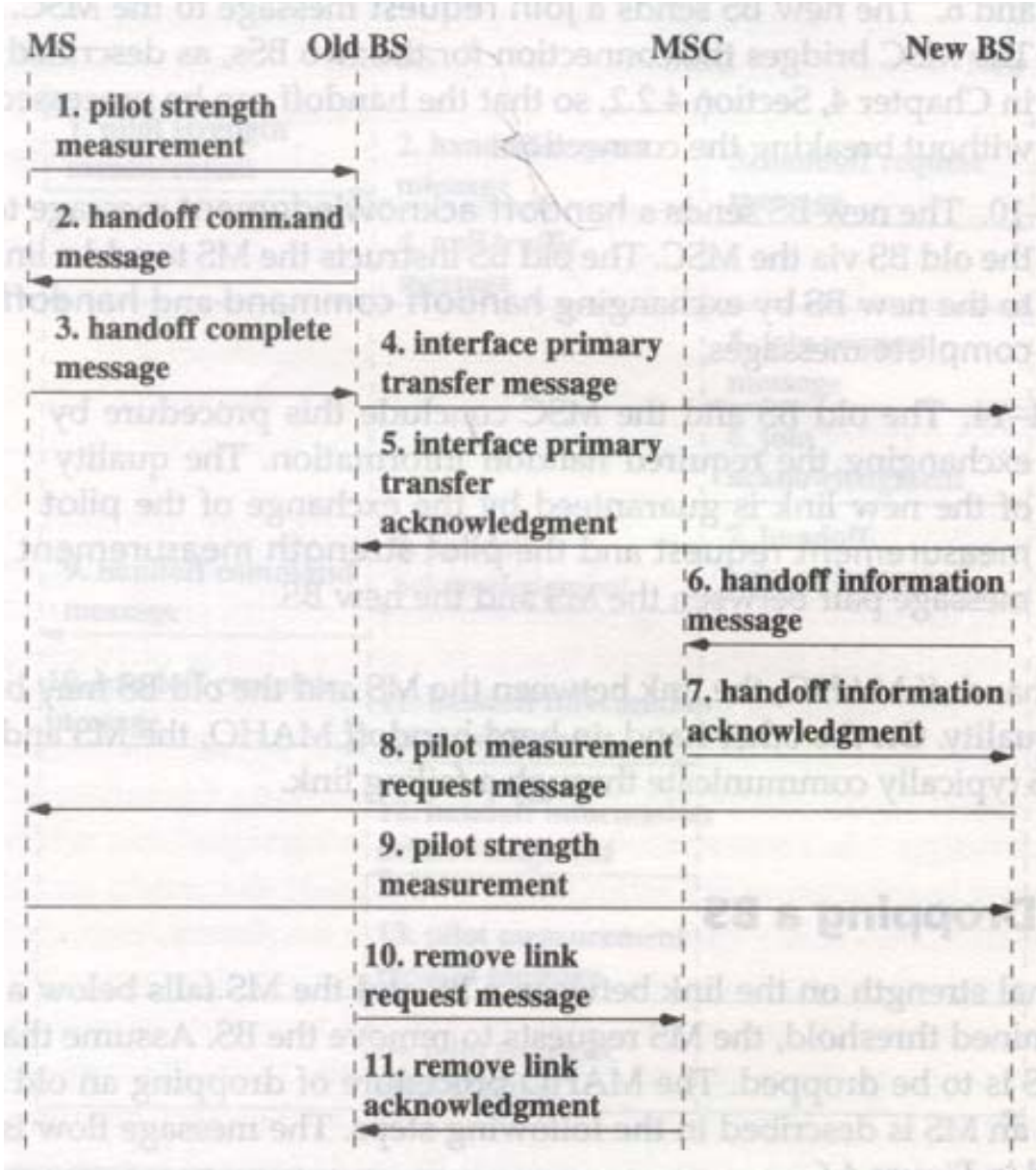
Message flow for subrating automatic link transfer

Soft Handoff

- CDMA allows many users to share a common frequency/time channel for transmission, and the user signals are distinguished by spreading them with different PN sequences.
- Also, an MS can transmit/receive the same information to/from several BSs if they have same PN sequence
- Signaling and voice information from multiple BSs are combined (or bridged) at the MSC, and the MSC selects the highest-quality signals from the BSs.
- Signaling and voice information must be sent from the MSC to multiple BSs, and the MS must combine the results
- Thus, within the overlap area of two cells, an MS can simultaneously connect to both the old and new BSs, and the link transfer procedure is no longer time-critical
- Focus on adding and removing BSs with MAHO soft handoff



Adding a new BS



Dropping the old BS

Acknowledgement

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