Handoff Functional Elements

an analysis of typical mobile systems

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Outline

- Terms and Modes
- Cold-start Functions
- H/O Functional Elements
- H/O Functions Mapped to Various Systems
- H/O Control Models
- Inter-RAT (multi-mode) Complexities

Terms and Modes

- Two different modes exist for typical cellular systems: Idle mode and Connected mode

	Station(STA) in Idle Mode	STA in Connected Mode
Service	no user service, monitor paging channel,	ongoing user service
	available service request channel	
Mobility Terms	cell selection/reselection	handoff (H/O)
Mobility Control	autonomous STA decision	usually controlled by network
Measurement	~100% of rcvr available for DL measurements	usually limited rcvr availability for measurments
Opportunities		(user service takes priority)
Measurement	not needed	all measurements usually reported to network
Reporting		
Coordination	uncoordinated, unscheduled reselection	usually cooordinated, scheduled H/O

- H/O always from
  source cell/sector ---> **target** cell/sector
- H/O based on **comparison** of source vs target

Cold-Start Functions (Idle mode only)

- Goal is to select any useable cell/sector for network entry
- Sequentially scan all channels (all Radio Access Technologies **(RATs)** if multi-mode capable)
- If signal detected, measure cell/sector DL quality
- If OK, receive broadcast System Information:
  - Network Info: Net ID, Net configuration, Neighbor list
  - Cell Reselection Algorithm using DL Quality parameter
  - Service Request Channel Parameters
  - Paging Channel parameters
- If Allowed Cell, Use Service Request Chan to Associate/Register/Authenticate
- Begin continuous cell reselection process while monitoring paging channel: search for better cell, compare selected cell to neighbors.

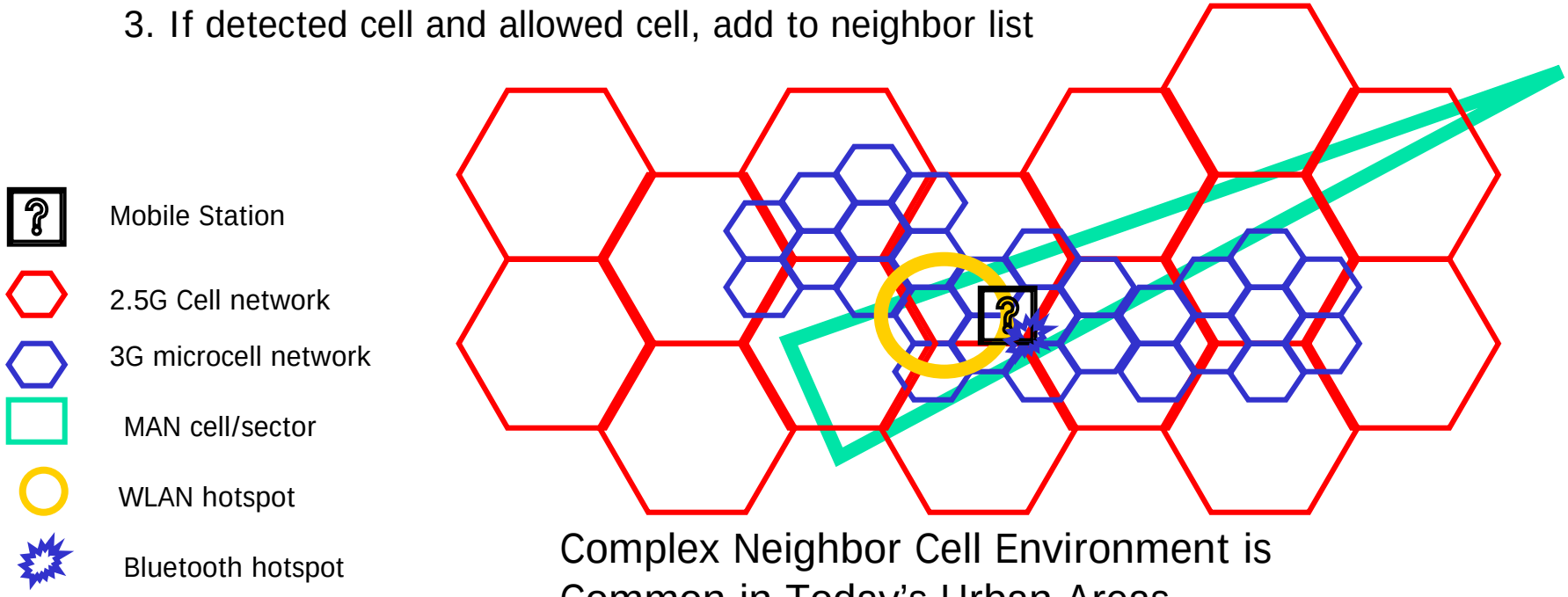
STA H/O Functional Elements

1 a.Receive Neighbor Cell List from Source Cell,

AND/OR

1b. Search for Neighbor Cells across all chans/RATs

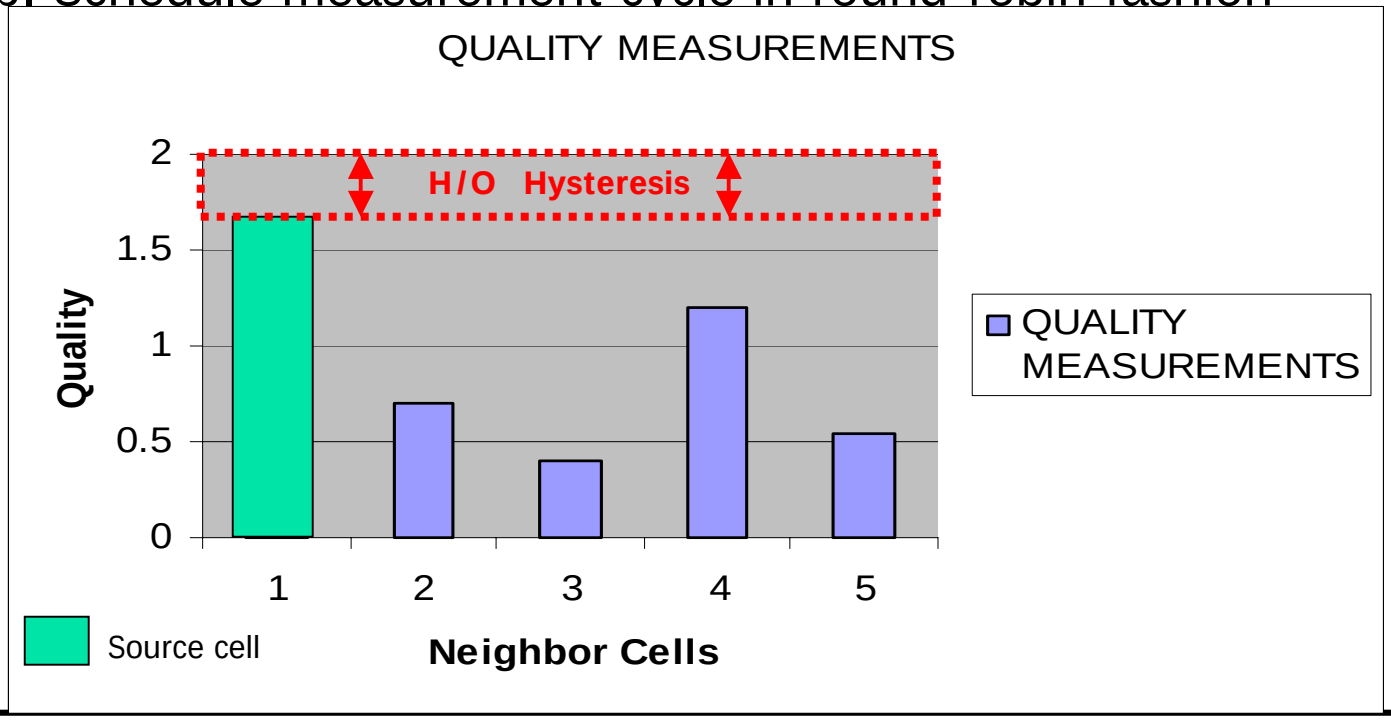
1. Schedule Discontinuous Receive (DRX) DL measurement opportunities (Conn only)
2. Use measurement opportunities to scan/probe/acquire cell in next chan/RAT
3. If detected cell and allowed cell, add to neighbor list



Complex Neighbor Cell Environment is Common in Today's Urban Areas

STA H/O Functional Elements (cont. 2)

- 2. Continuously measure source cell quality (network may measure UL)
- 3. Periodically measure DL quality of all neighbor cells (H/O targets)
  - a. Schedule DRX DL measurement opportunities (Conn only)
  - b. Schedule measurement cycle in round-robin fashion



STA H/O Functional Elements (cont. 3)

- 4. Apply H/O decision
  - a. Report measurement results to network (Conn only)
  - b. Apply decision algorithm: e.g. best cell with hysteresis considering cell capacity and Configuration Management (CM)
- 5. If H/O decided:
  - a. Network signals coordinated H/O to source and target cells (Conn only)
  - b. Network orders STA to execute H/O (Conn only)
  - c1. STA quits source cell and switches to target (hard H/O)
  - **OR**
  - c2. STA adds and/or deletes active radio link from set (soft H/O)
  - d. STA signals presence on new source cell (Idle only)
- Repeat steps 1-5: continuous H/O assessment

H/O Functional Mapping on Wireless Systems

- These basic H/O functions may be mapped onto existing Radio Access Technologies.
- Comparisons between RATs indicate functional modifications which may be needed to provide increased mobility for systems which do not currently support H/O .

	WIRELESS SYSTEM (RAT)					
H/O Function	**802.11**	**802.16**	**GSM**	**W-CDMA**	**CDMA2K**	
Initial channel scan	yes	yes	yes	yes	yes	
Initial inter-RAT scan	no	no	no	limited	?	
Useable Cell Selection	yes	yes	yes	yes	yes	
Rcv Sys Info/Neighbor List	limited	limited	yes	yes	yes	
Search for Neighbor Cells	limited	no	limited	limited	limited	
Measure Source Quality	yes	yes	yes	yes	yes	
Sched Measure Opportunity	no	no	yes	yes	yes	
Measure Neighbor Quality	limited	no	yes	yes	yes	
Report Measurements	no	no	yes	yes	yes	
H/O Decision Element	STA	N/A	Network RRM	Network RRM	Network RRM	
Scheduled H/O	no	no	optional	optional	optional	
Hard H/O	yes	no	yes	yes	yes	
Soft H/O	N/A	N/A	N/A	optional	optional	

Radio Resource Management Control Models(RRM)

- Typical Mobile Systems control H/O functions using a centralized, network-based RRM entity (L3 & up), with complex L1/L2/L3 signalling.
- RRM decides on H/O using more than just the comparative cell quality measurements made by the STA. Additional RRM H/O decision inputs include:
  - Capacity loading (UL and DL) in target cells
  - Interference levels in target cells
  - Congestion control (overloaded condition) in target cells
  - Configuration Management of target cells
  - Other vendor proprietary considerations to maximize network performance
- Typical 802.11 systems use STA-based control functions with simple L1/L2 signalling and without upper layer involvement.
- By using an enhanced SNMP Management Information Base (MIB), or with additional L3 signalling, 802.11 systems could support centralized, mobile-network-style RRM .
- Simplified control models are presented here.

WLAN H/O Control Model

- STA configures measurements and selects Access Point (AP) from set of available neighbor APs.
- If measurements indicate a “better” AP, STA may autonomously reassociate with new AP (handoff), though this behavior is not standardized.
- Reassociation may trigger source/target AP coordination for IP reroute (IAPP)
- Not very compatible with centralized RRM paradigm used for mobile networks and internetwork management.
- Enhanced MIB could be used to post STA capabilities and measurement results

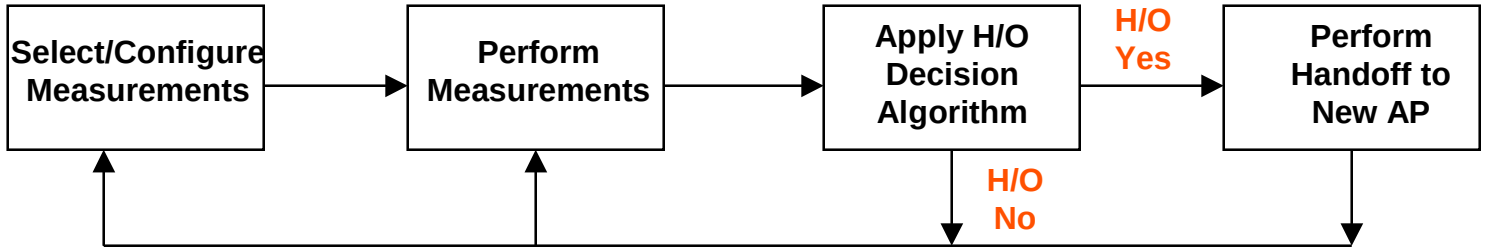


Figure 1. STA Functions for AP Handoff

Cellular Control Model: Cell Selection/Reselection

- STA has no ongoing services and is in idle mode, monitoring for incoming calls or pages or packets.
- RRM broadcasts System Information parameters to all STAs with details about measurements, neighbor cells and reselection decision parameters.
- STA configures measurements per global RRM broadcast.
- STA autonomously applies global reselection algorithm.
- STA reassociates autonomously, then may perform update procedure to inform RRM of new association.
- Similar to WLAN Control Model, but may be implemented differently.

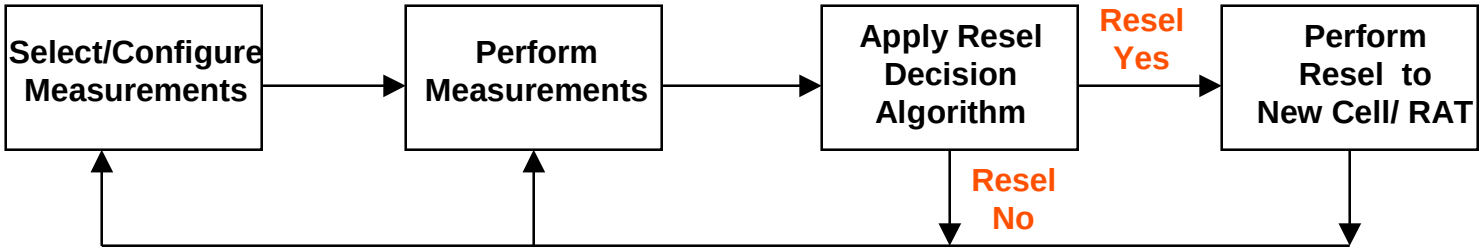


Figure 2. STA Functions for Inter-RAT Reselection

Cellular Control Model: Handoff (H/O)

- STA is "connected" to network and real-time, circuit-style user services are ongoing. Note: H/O is not used for certain non-real-time data services.
- RRM configures measurements.
- STA performs measurements and reports/posts results to RRM.
- RRM decides and coordinates H/O between STA and source/target Cells.
- Compatible with 802.11 control paradigm with added L3 signalling or MIB modifications.

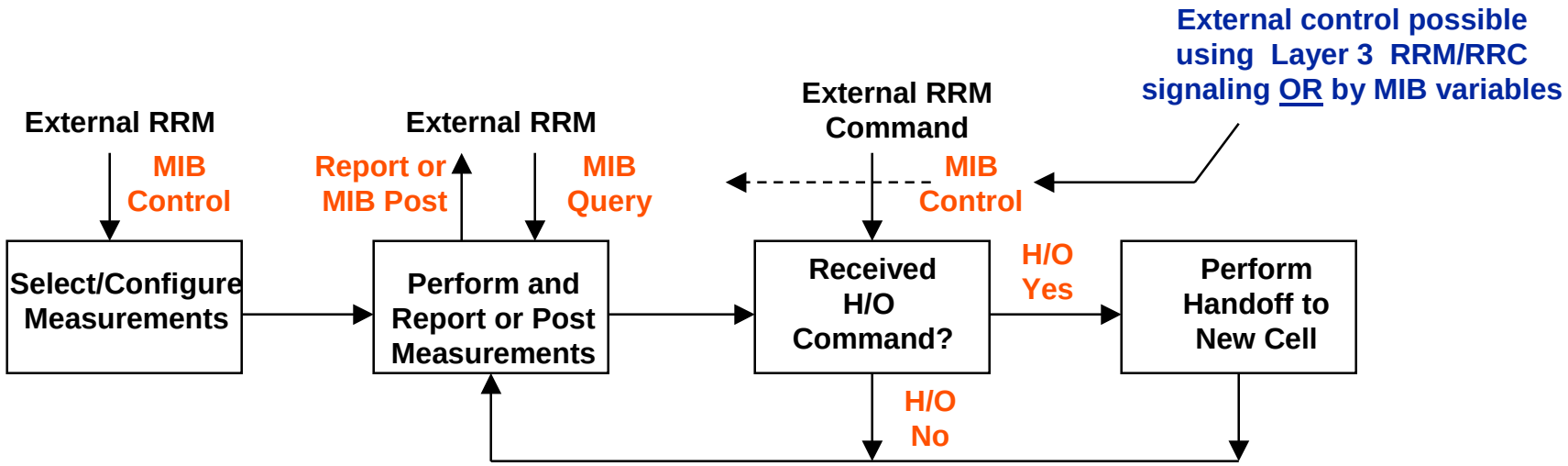


Figure 3. STA Functions for Cellular Handoff

Inter-RAT Functional Complexities:

- Within 802.11, new multi-mode devices will permit inter-RAT operations among 802.11b, 802.11a, and 802.11g.
- Alternate WLAN technologies require inter-RAT operation with 802.11, as evidenced by new WIG initiative at September meeting:
  - ETSI Hyperlan2
  - ARIB MMAC
- New WLAN-type data services will be offered with many other radio access technologies, including cellular:
  - 3GPP W-CDMA
  - 3GPP2 CDMA2000 (CDMA2K)
  - Bluetooth
  - GSM/GPRS
- For Multi-mode capable devices, H/O to other RATs must be considered.

Inter-RAT Handoff Matrix

HANDOFF		to RAT								
		802.11a	802.11b	802.11g	HL2	MMAC	Bluetooth	W-CDMA	CDMA2K	GPRS
from	802.11a	N/A								
RAT	802.11b		N/A							
	802.11g			N/A						
	HL2				N/A					
	MMAC					N/A				
	Bluetooth						N/A			
	W-CDMA							N/A		
	CDMA2K								N/A	
	GPRS									N/A

- 6 different Handoff scenarios to analyze for intra-802.11 operations.
- 12 additional Handoff scenarios to analyze for WIG interworking.
- 24 additional Handoff scenarios to analyze for other identified wireless data RATs.
- Measurement opportunities need coordination between source and target RAT.
- DL Quality parameter(s) may vary between source and target RAT.
- Lack of network-based inter-RAT H/O coordination entity.

Mobility with Multiple Radio Access Technology Devices

- Each inter-RAT handoff scenario must consider the same issues:
  - Identification of collocated RATs (scan for other available h/o options or monitor broadcast info for collocated network)
  - Select measurements in both source and target RAT
  - Create measurement opportunities in source RAT, i.e. time periods during which radio may switch frequencies/modes to measure in target system:
  - Does User/Operator agreement permit operation on target RAT? Roaming/Billing issues?
  - Who controls handoff decision threshold?
  - Use of handoff to mitigate inter-cell interferance or for CM?
  - Coordinated, scheduled handoff or uncoordinated handoff?

- **Multi-mode, radio aware terminals must address these issues.**

Coordinated Inter-RAT Radio Resource Management (CRRM)

- 3G mobile systems support inter-RAT H/O: source and target RATs maintain separate RRM entities which operate with different decision algorithms.
- In current standards, the **source** RRM entity **decides** to H/O to target RAT with little negotiation. This may introduce conflicting decisions between soource/target RRM entities, with potential ping-pong results.
- 3GPP is currently developing techniques for Coordinated Radio Resource Management (CRRM) across multiple RATs:
  - Preliminary Concept: New CRRM network element using agreed policies to dynamically control H/O "weighting factors" between each network in the inter-RAT matrix. Weighting factors to be adjusted periodically for the specific conditions in each network in each local area.
  - Control policies to be specified and agreed by all participating operators.
  - Network operators permit dynamic RRM modifications for inter-RAT H/O based on these externally generated weighting factors.
- Requires not only new standards, but may require internetwork operating agreements.

References

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- Third Generation Partnership Project (3GPP) standards (available on website www.3gpp.org):
  - Technical Specification 25.133, Requirements for Support of Radio Resource Management, ver 5.4.0, (filename 25133-540.zip)
  - Technical Specification 25.331, Radio Resource Control (RRC) Protocol Specification, ver 5.2.0, (filename 25331-520.zip)
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  - Technical Report 25.922, **Radio Resource Management Strategies**, ver 5.0.0, (filename 25922-500.zip)
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