IETF Nov 2015: IEEE 802.11 multicast capabilities

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Abstract

- This file contains a description of selected IEEE 802.11 multicast optimization capabilities and their benefits, for presentation at a November 2015 IETF INT area session.
- Development of this material is in response to questions from IETF participants on IEEE 802.11 multicast performance, see https://www.iab.org/wp-content/IAB-uploads/2013/01/multicast-problem-statement.pptx.

Agenda: 802.11 multicast optimization features

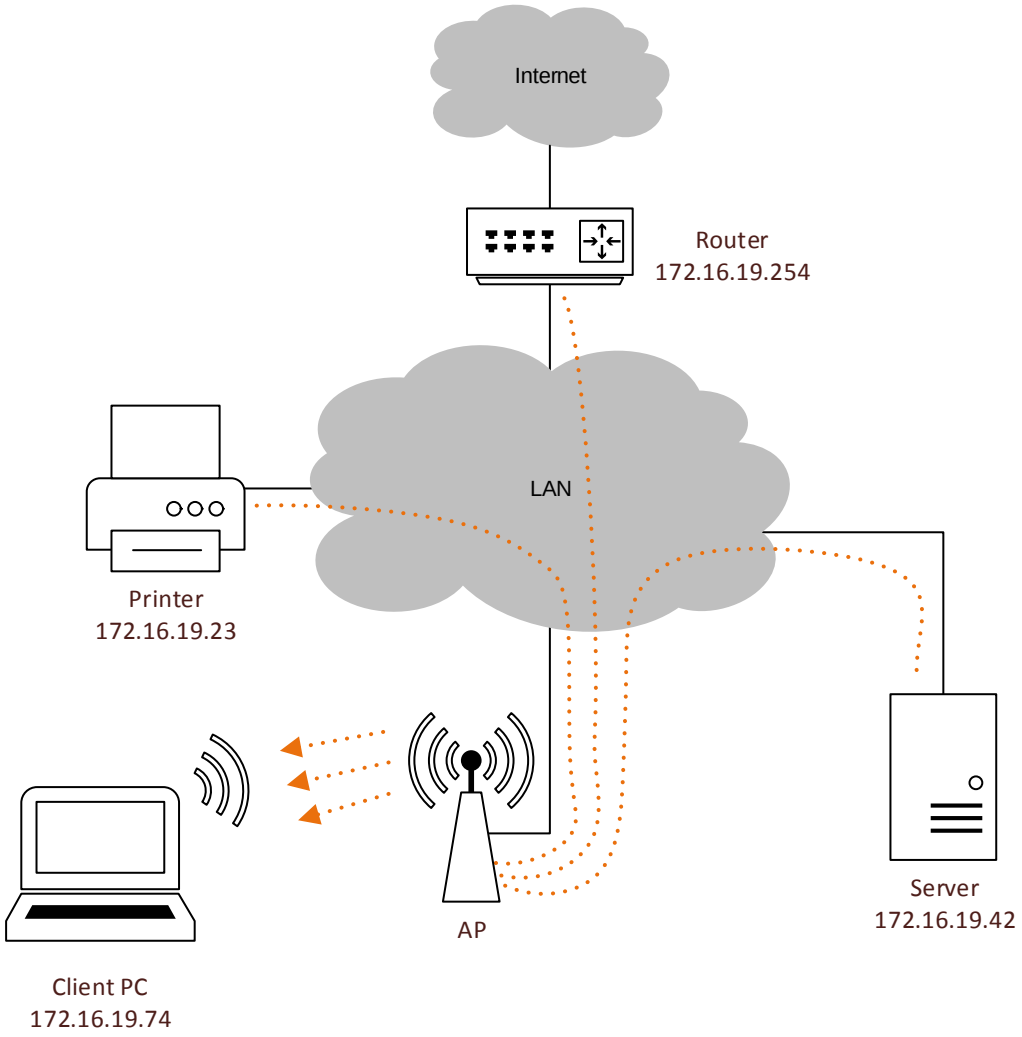
- **Multicast in 802.11**
- IEEE Std 802.11-2012 Proxy ARP Description
- Directed Multicast Service (DMS)
- GroupCast with Retries (GCR) Description
- Implementation Status of Optimization Features
- Back-up GCR Details
- References

802.11 Packet Transmission

- 802.11 operates in unlicensed frequency bands. There are no guarantees that any traffic gets through.
- 802.11 MAC layer packets can be lost due to collision, interference, poor rate adaptation decisions, changes in the radio channel (e.g. walking behind a steel-reinforced pillar).
- A 10% “packet error ratio” is not unreasonable, but this is metric with a *lot* of noise in it.
- Unicast traffic is retried up to some limit (typically 4-12 times). This improves reliability, but it’s still subject to higher-layer packet loss

How does Multicast affect WLANs?

- **AP extends wired segment**
  - All broadcast frames on LAN side copied to WLAN
  - In WLAN, broadcast messages transmitted at most robust MCS
  - Most robust MCS implies large frames sent at slow rate



802.11 multicast properties

- **Multicast / broadcast traffic is generally not retransmitted, because there is no acknowledgement**
- **Multicast / broadcast traffic is generally sent at a "lowest common denominator" rate, known as a basic rate. This might be as low as 6 Mbps, when unicast links are operating at 600 Mbps.**
- **Lower rate → larger frame, less airtime for everything else.**
- **There are options, that are not commonly implemented or certified to improve multicast reliability –**
  - GroupCast with Retries (GCR) - Greater reliability is provided via unsolicited retries or the block ack mechanism
  - Directed Multicast Service (DMS) – convert unicast to multicast

802.11 and power save

- **Both unicast and multicast traffic can be delayed by power-saving mechanisms.**
- **Unicast is delayed until a STA wakes up and asks for it. Additionally, unicast traffic may be delayed to improve power save, efficiency and increase probability of aggregation.**
- **Multicast traffic is delayed in a wireless network if any of the STAs in that network are power savers. All STAs are awake at a known time to receive multicast traffic.**
- **Packets can also be discarded due to buffer limitations in the AP and non-AP STA.**

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Proxy ARP in 802.11-2012

- **The AP knows all associated STA's MAC address and IP address**
  - AP acts as central "manager" in BSS
- **AP acts on behalf of STAs**
  - Power save relies on AP buffering data for STAs
- **Proxy ARP easy to implement at AP**

- **Advantages**
  - Less low MCS broadcast traffic on wireless medium
  - STA benefits from extended power save in sleep mode as ARP requests are replied to by AP

Proxy ARP in 802.11-2012

- **When the AP supports Proxy ARP "*[…] the AP shall maintain a Hardware Address to Internet Address mapping for each associated station, and shall update the mapping when the Internet Address of the associated station changes. When the IPv4 address being resolved in the ARP request packet is used by a non-AP STA currently associated to the BSS, the proxy ARP service shall respond on behalf of the non-AP STA*"**
  - Keeps ARP frames off the wireless medium
  - See 10.23.13 in [2]

ARP and IPv6?

- **IPv6 doesn't need ARP**
  - IPv6 uses Neighbor Discovery Protocol (NDP) instead
- **Every IPv6 node subscribes to special multicast address**
  - Neighbor-Solicitation message replaces ARP
- **NDP may be used to request additional information**
  - Maximum Transmission Unit
  - Router Solicitation
  - Router Advertisement, etc.
- **NDP messages are sent as group addressed (broadcast) frames in 802.11**

IPv6 support in 802.11-2012

- ***"When an IPv6 address is being resolved, the Proxy Neighbor Discovery service shall respond with a Neighbor Advertisement message […] on behalf of an associated STA to an [ICMPv6] Neighbor Solicitation message […]. When MAC address mappings change, the AP may send unsolicited Neighbor Advertisement Messages on behalf of a STA."***
  - 802.11 Proxy ARP prepared for IPv6
  - Keep NDP messages off the wireless medium
  - See 10.23.13 in IEEE P802.11-2012

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Directed Multicast Service (DMS)

- DMS enables a client to request that the AP transmit group addressed frames destined to the requesting client as individually addressed frames.
- AP transmits group addressed frames to the requesting client as individually addressed frames
- Requires 11n A-MSDUs
- Individually addressed frames are acknowledged and are buffered for power save clients
- Requesting STA specifies traffic characteristics for DMS traffic
- DMS was defined in IEEE Std 802.11v-2011

Groupcast with Retries (GCR)

- AP transmits each group addressed frame as conventional group addressed transmission. Retransmissions are group addressed, but hidden from non-11aa clients
- A directed block acknowledgement scheme is used to harvest reception status from receivers, and the retransmissions are based upon these responses.
- GCR is suitable for all group sizes including medium to large groups. As the number of devices in the group increases, GCR can send block acknowledgement requests to only a small subset of the group.
- GCR increases probability of broadcast frame reception success, but still not a guarantee
- GCR was defined in IEEE Std 802.11aa-2012

Issues and continuing improvement re: GCR with Block Acknowledgement

- **May introduce unacceptable latency**
  - After sending a group of data frames to the group, the AP has to unicast Block Ack Request to a subset of members; wait for the corresponding Block Ack; retransmit any missed frames and then resume
  - This latency may not be acceptable for some traffic
- **There are ongoing extensions in 802.11 to improve GCR performance**
  - BAR is send using downlink MU-MIMO (DL MU-MIMO is already in 802.11-REVmc 4.3)
  - BA is sent using uplink MU-MIMO (uplink MU-MIMO is a .11ax feature)
  - Additional 802.11ax extensions are under consideration, see https://mentor.ieee.org/802.11/dcn/15/11-15-0800-00-00ax-multiplexing-of-acknowledgements-for-multicast-transmission.pptx . The latency is reduced by simultaneously receiving BA information from multiple clients

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Multicast Optimization Implementation

- **An 802.11 AP manufacturer might optimize certain multicast-related behaviors**
- **There's nothing in the standard to stop an implementer from turning multicast into unicast traffic**
  - Most enterprise AP vendors implement multicast to unicast (proprietary mechanisms)
- **Implementation Status of Proxy ARP and Proxy ND**
  - Implemented primarily in enterprise-grade systems
  - Not widely implemented in small office/home systems at this time
- **GCR and DMS not currently implemented in product**

Questions?

More information on GCR implementation

For reference/back-up

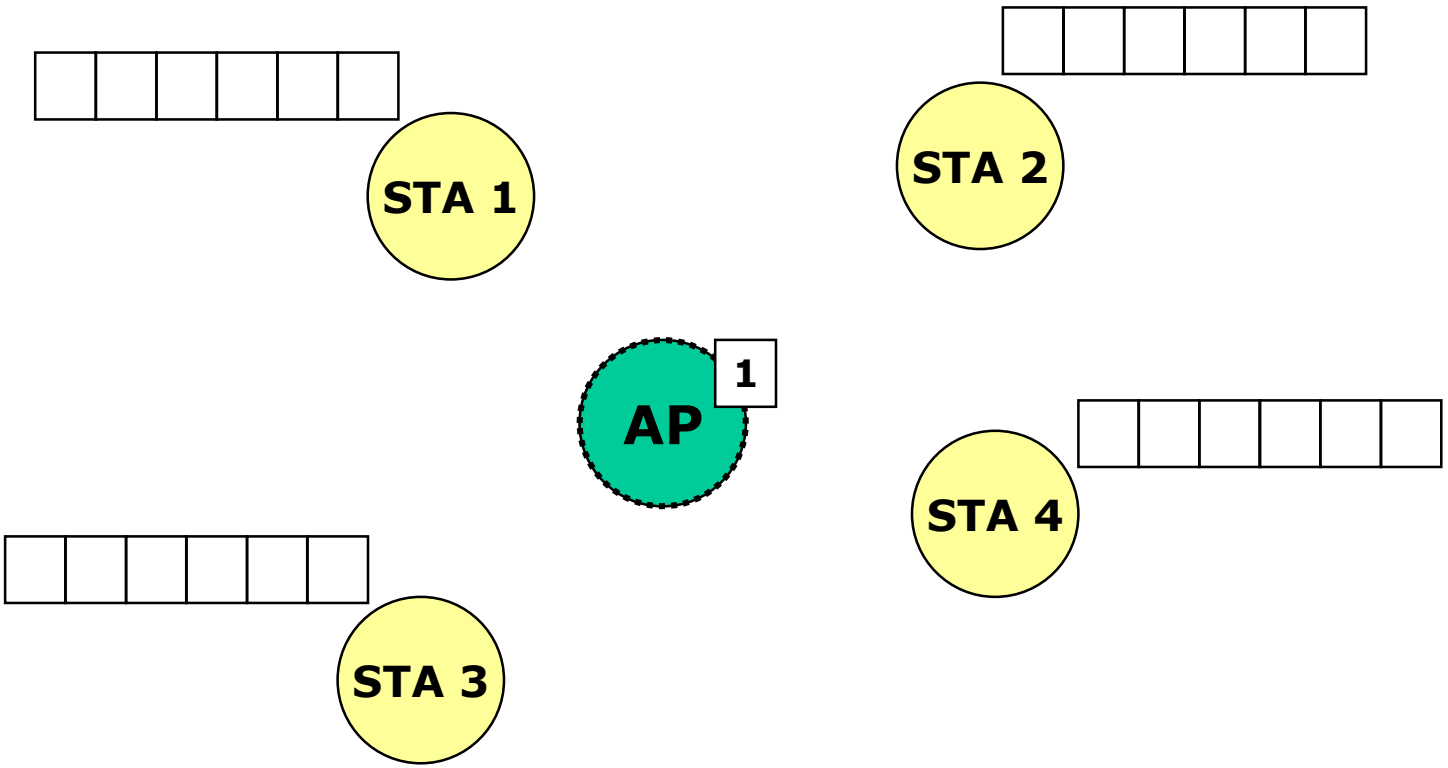
GCR mechanism details

- **GCR announcement, set up, modification and tear down use DMS Request / DMS Response frames**
  - DMS Request / DMS Response elements with addition of GCR Request / GCR Response sub-elements
- **AP can discover the STAs receiving a group address**
  - Explicit 11aa Group Membership Request / Response frame exchanges
  - Non-802.11 methods (e.g. IGMP snooping)
- **Additional policies for group addressed frames:**
  - ***GCR Block ACK***
    - Suited to medium number of group members.
      Initiates BA agreement with each group member. Transmitting AP regularly sends BAR to the STAs.
  - ***GCR unsolicited retry***
    - Suited to large number of group members
      Retransmit MSDU one or more times to increase probability of success.

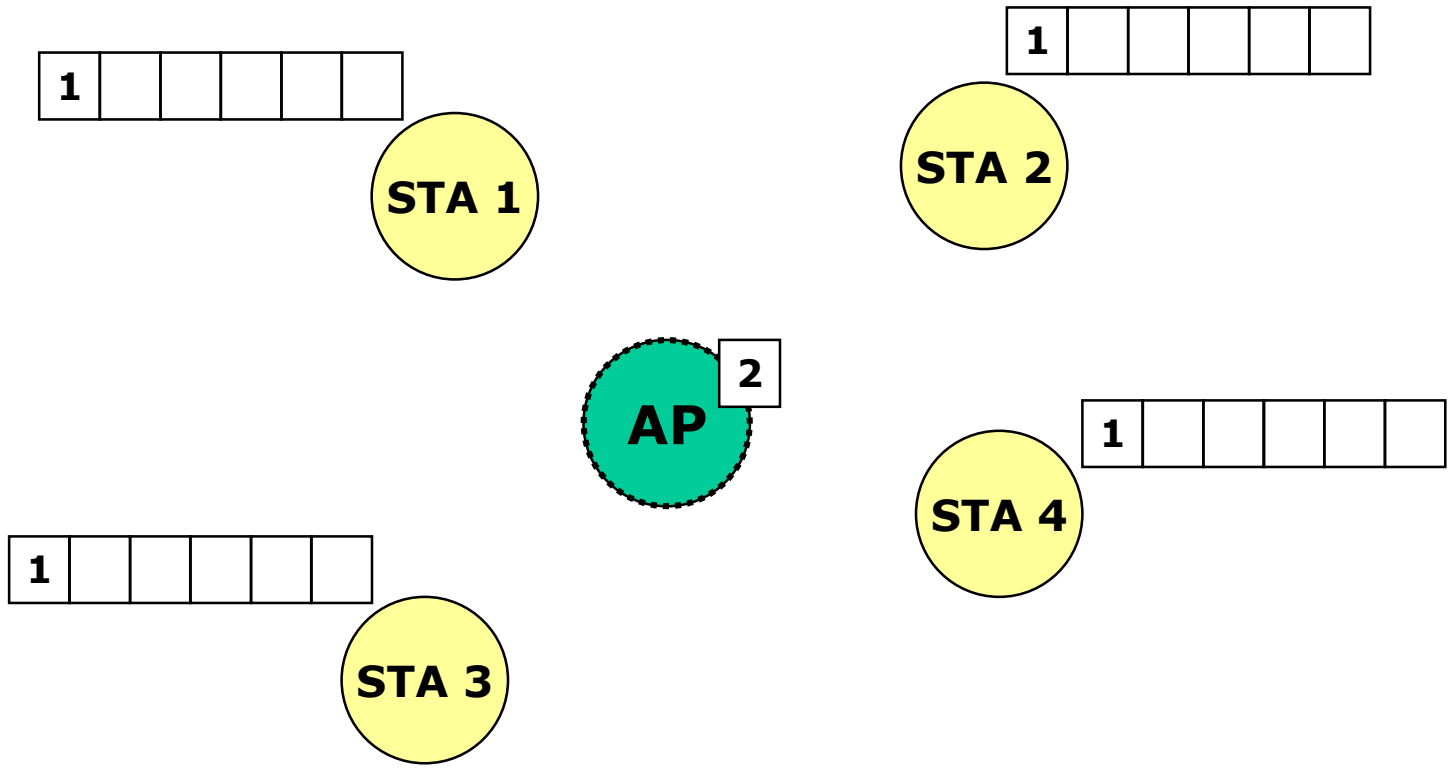
GCR Concealment

- **"Hidden" frames from non-11aa STAs**
  - Retransmissions using GCR Block Ack or GCR Unsolicited Retry
  - All GCR-SP transmissions
- **"Original" MSDU is encapsulated inside an A-MSDU**
  - To preserve the original destination address
  - Same Sequence Control value of frame containing A-MSDU as the frame that contained original MSDU
  - Retry field = 1
- **A-MSDU is sent to the "GCR Concealment Address"**
  - Allocated GCR Concealment MAC address 01-0F-AC-47-43-52
    - but can be any group address from an allocated OUI.

Block ACK for Multicast



Block ACK for Multicast



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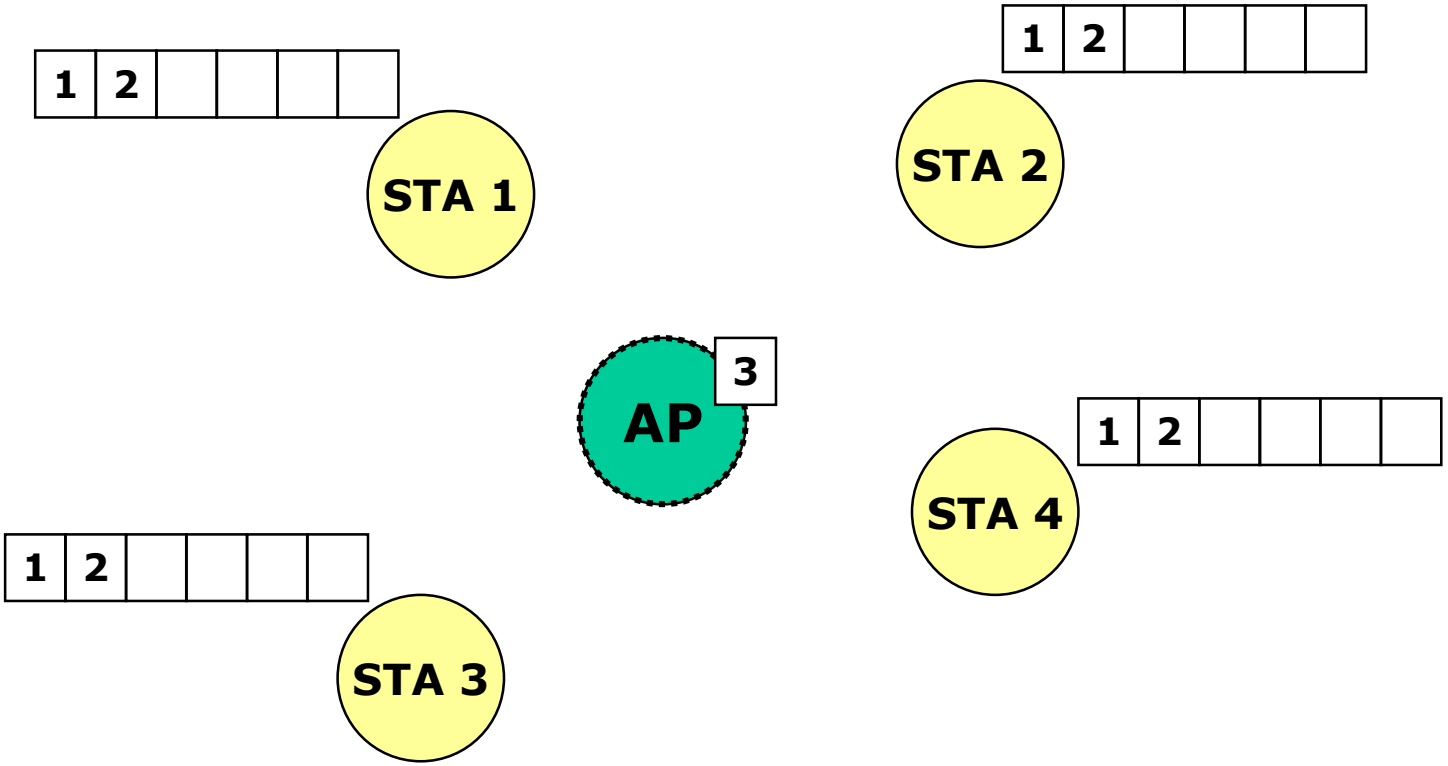

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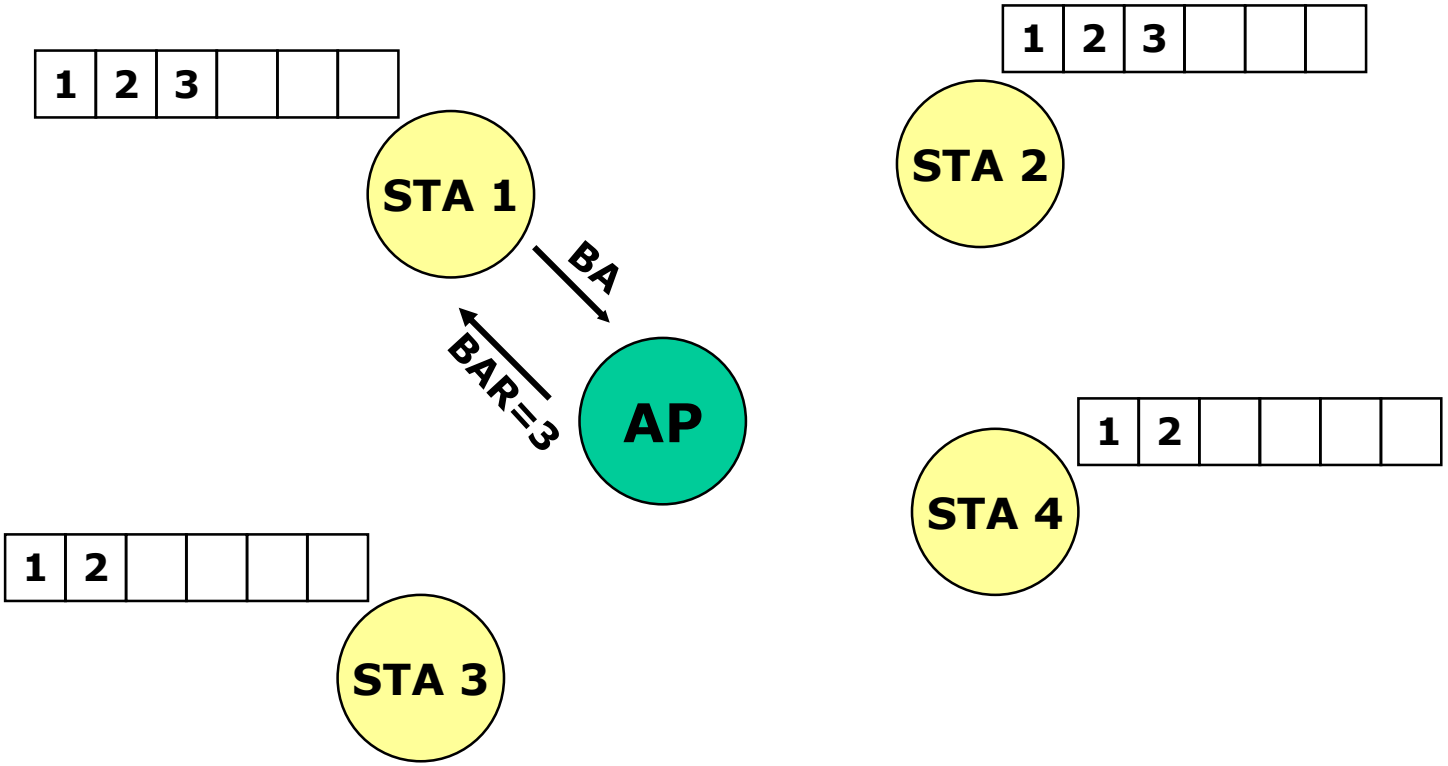

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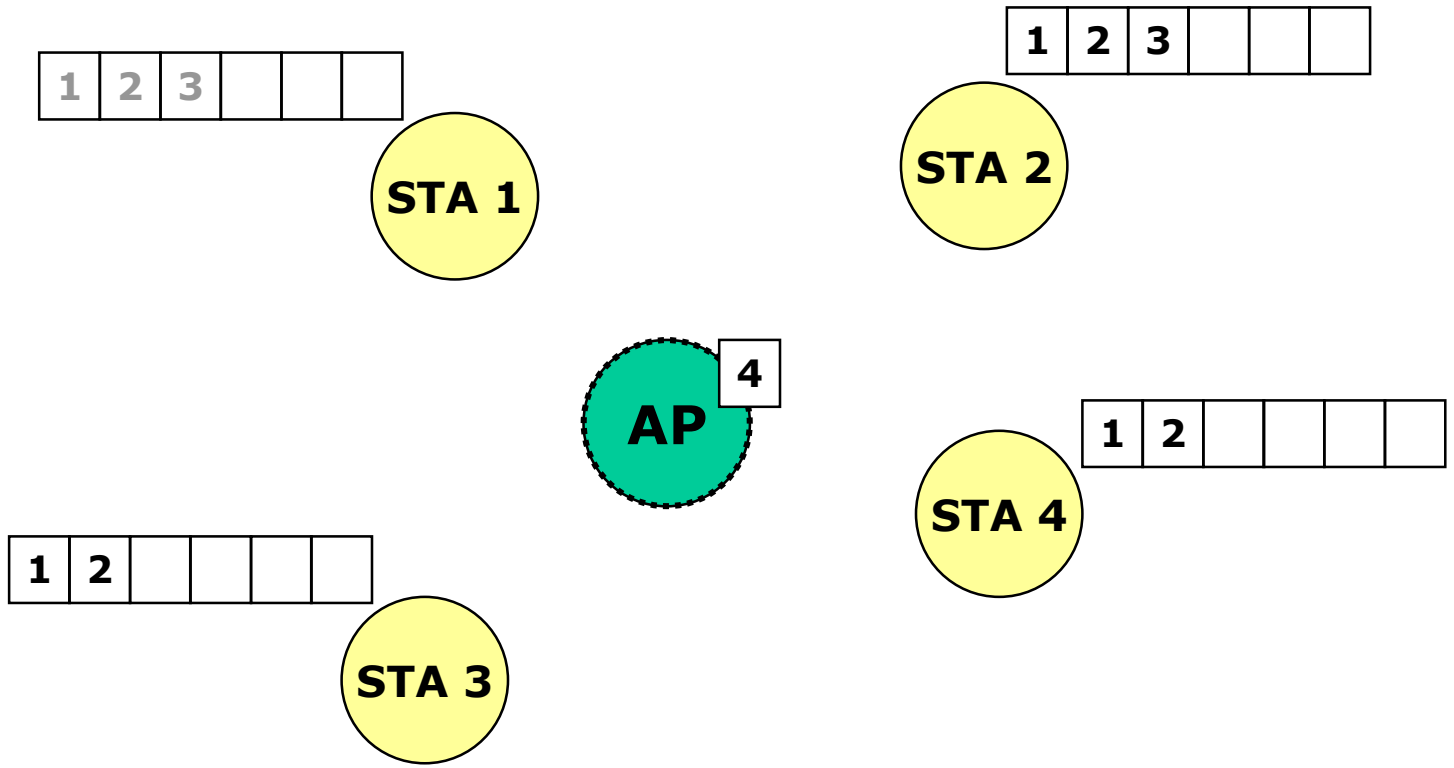

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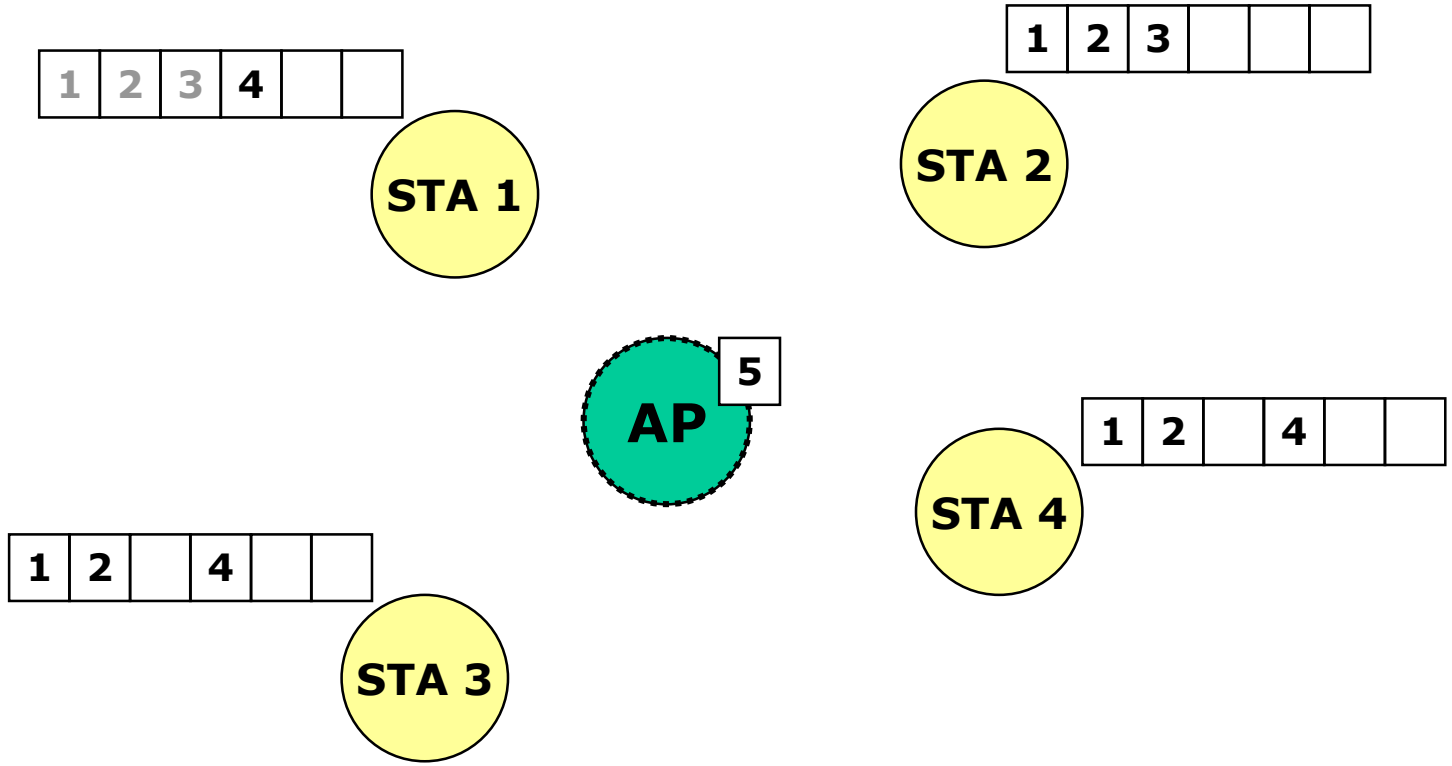

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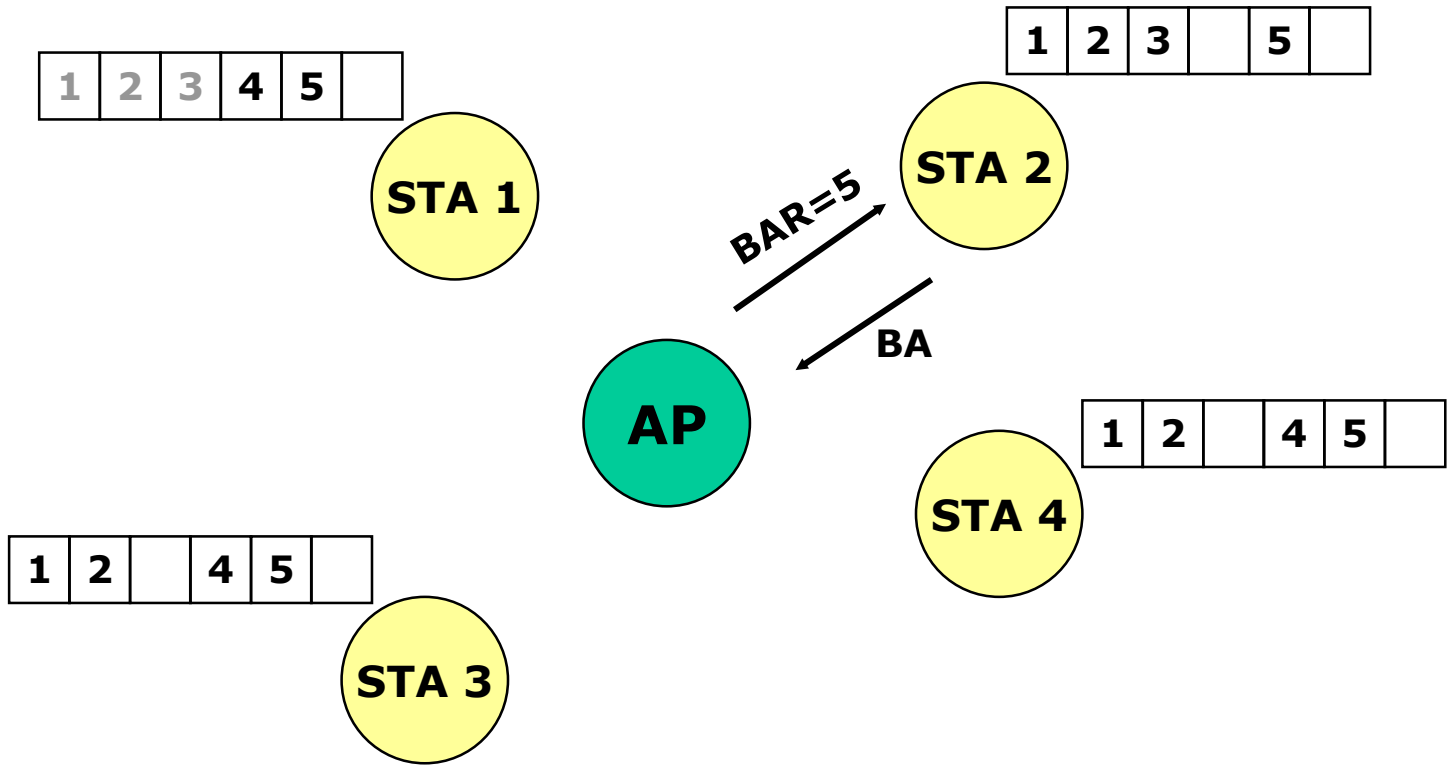

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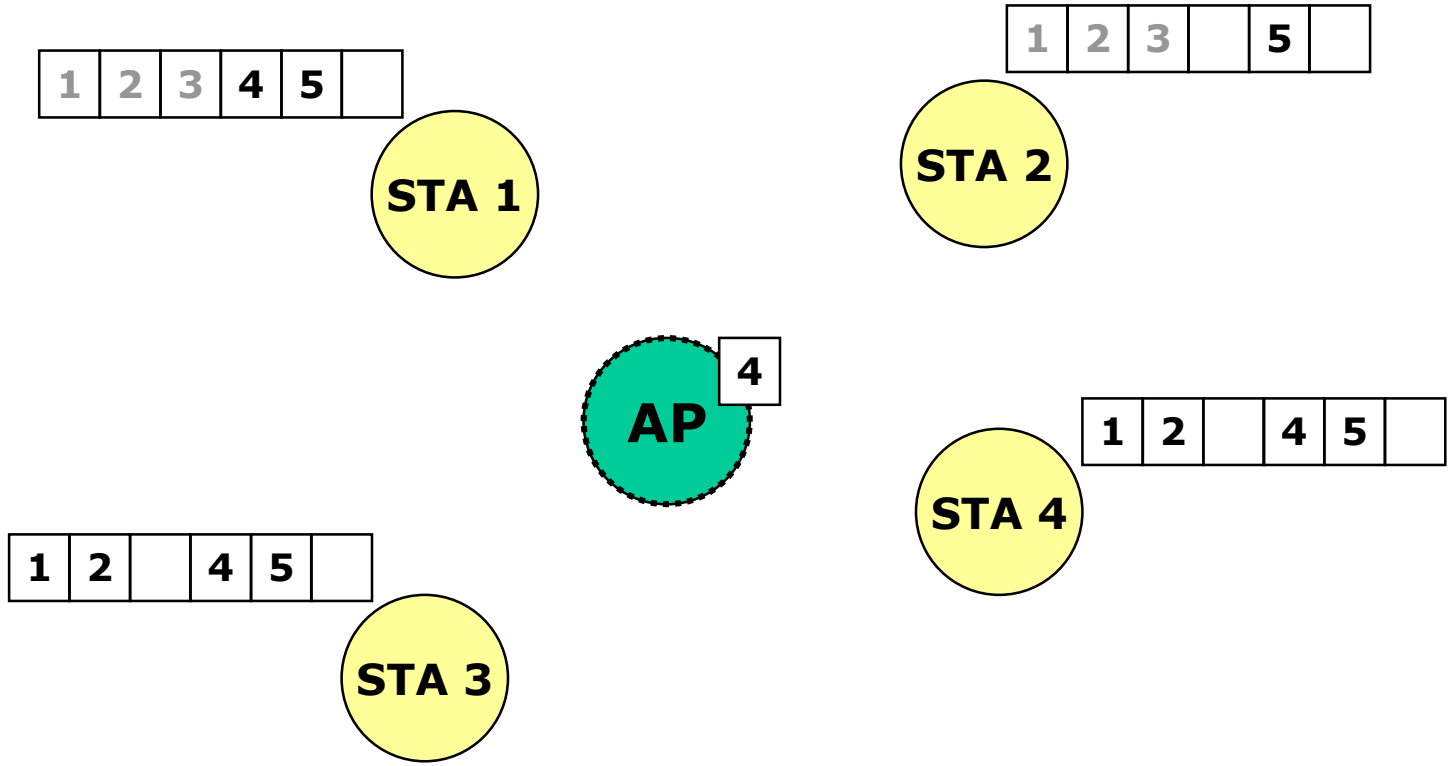

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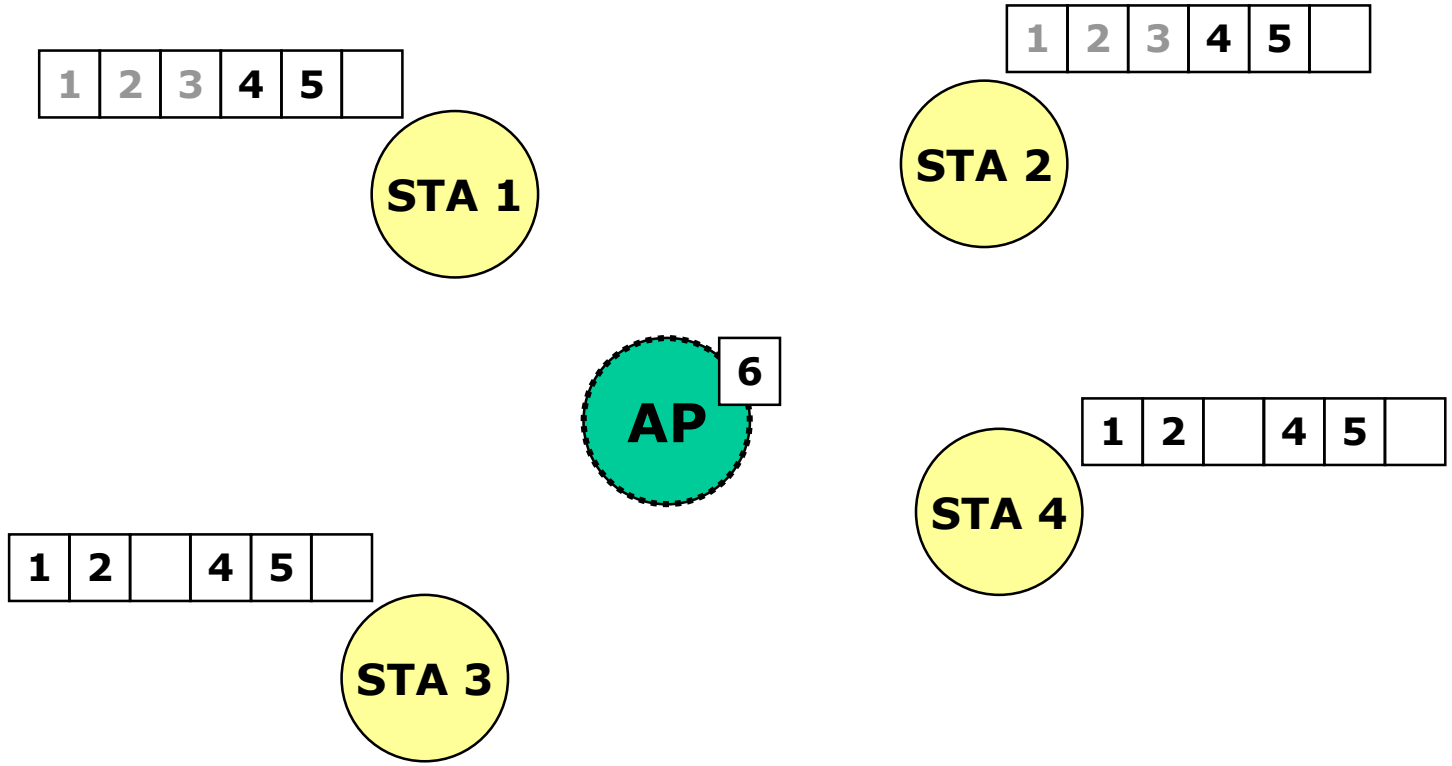

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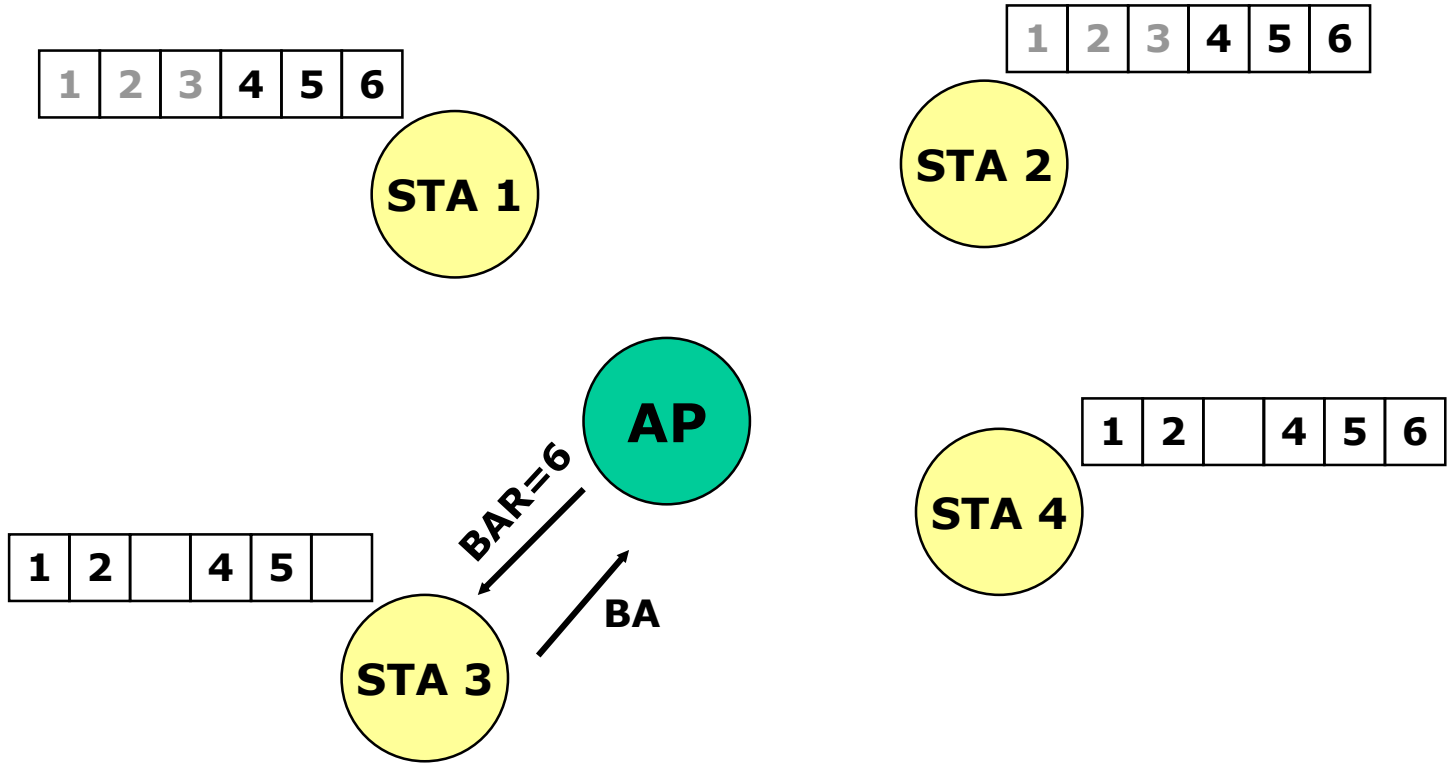

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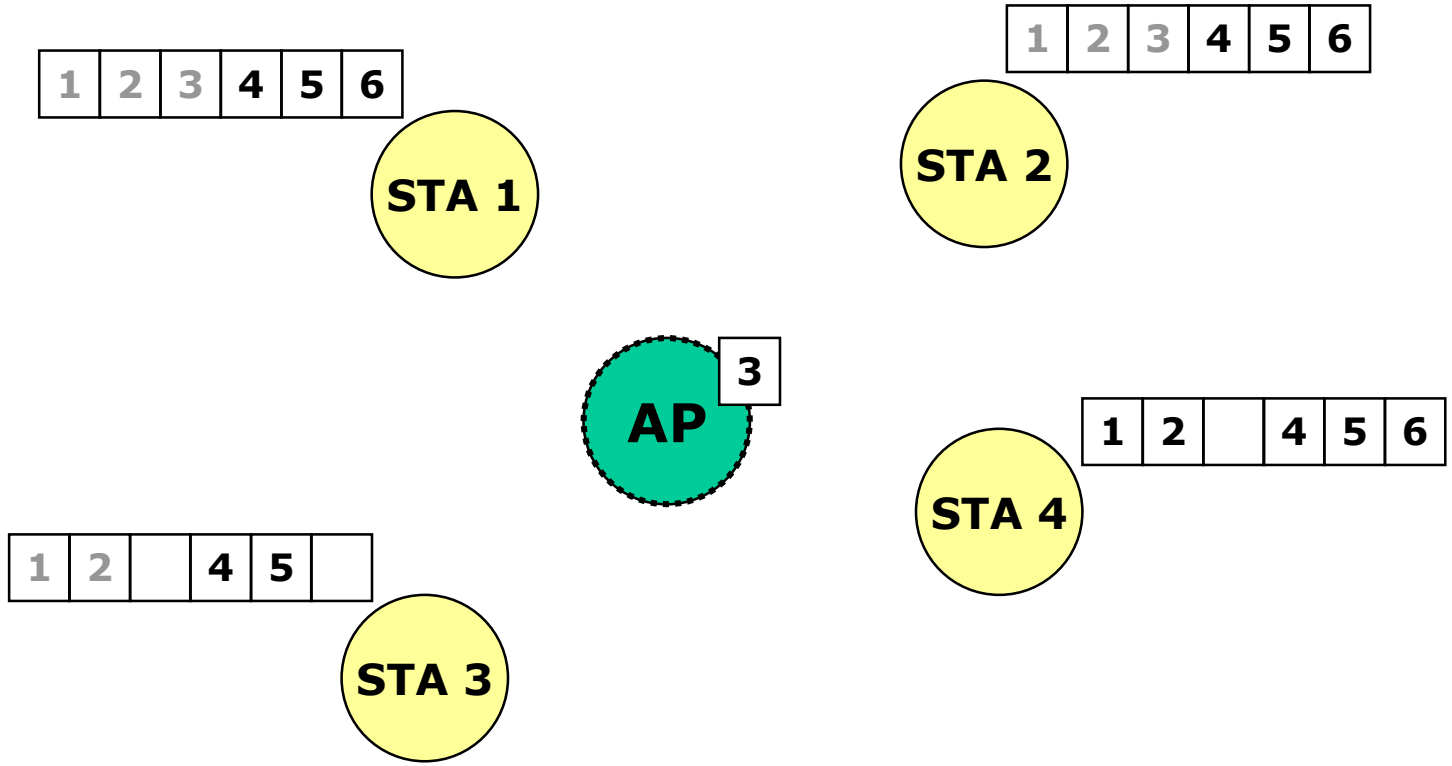

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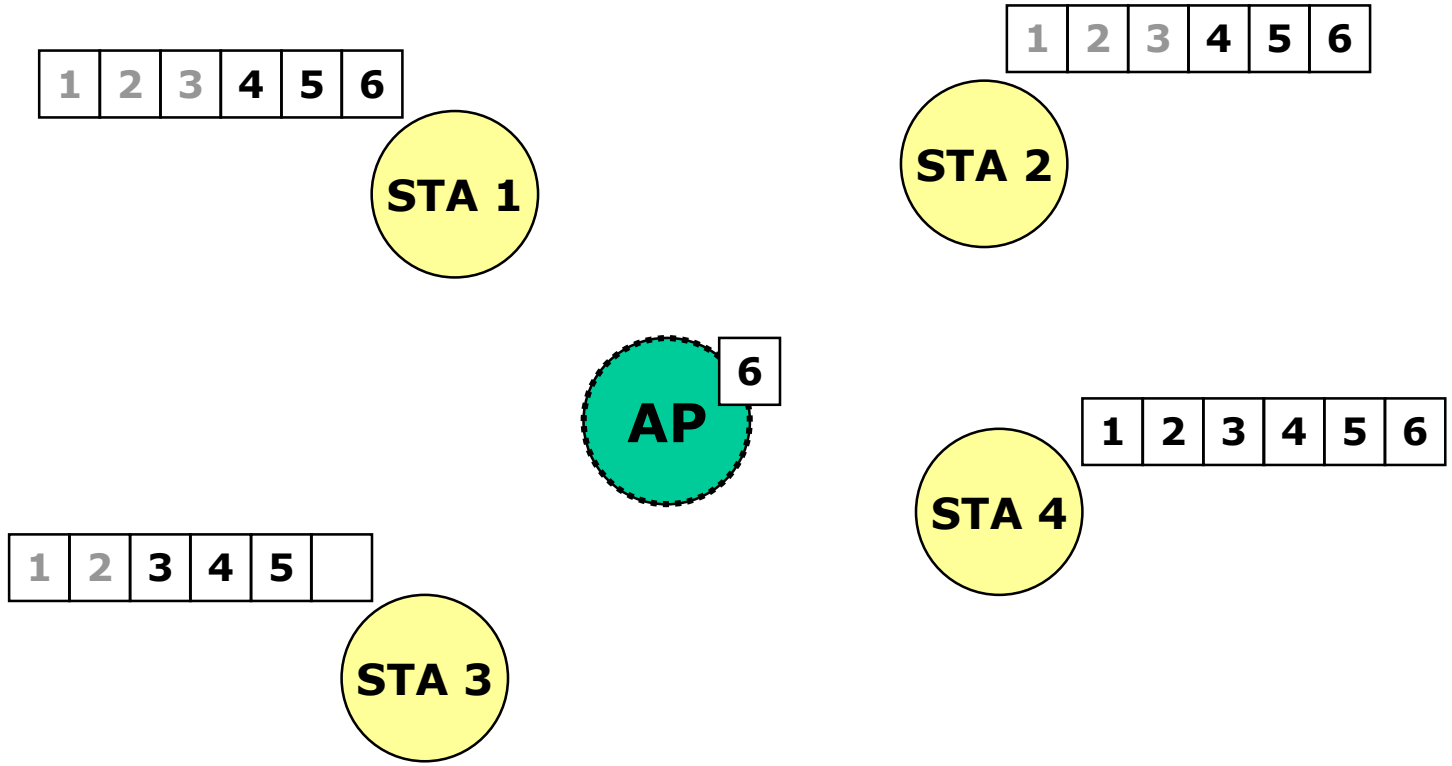

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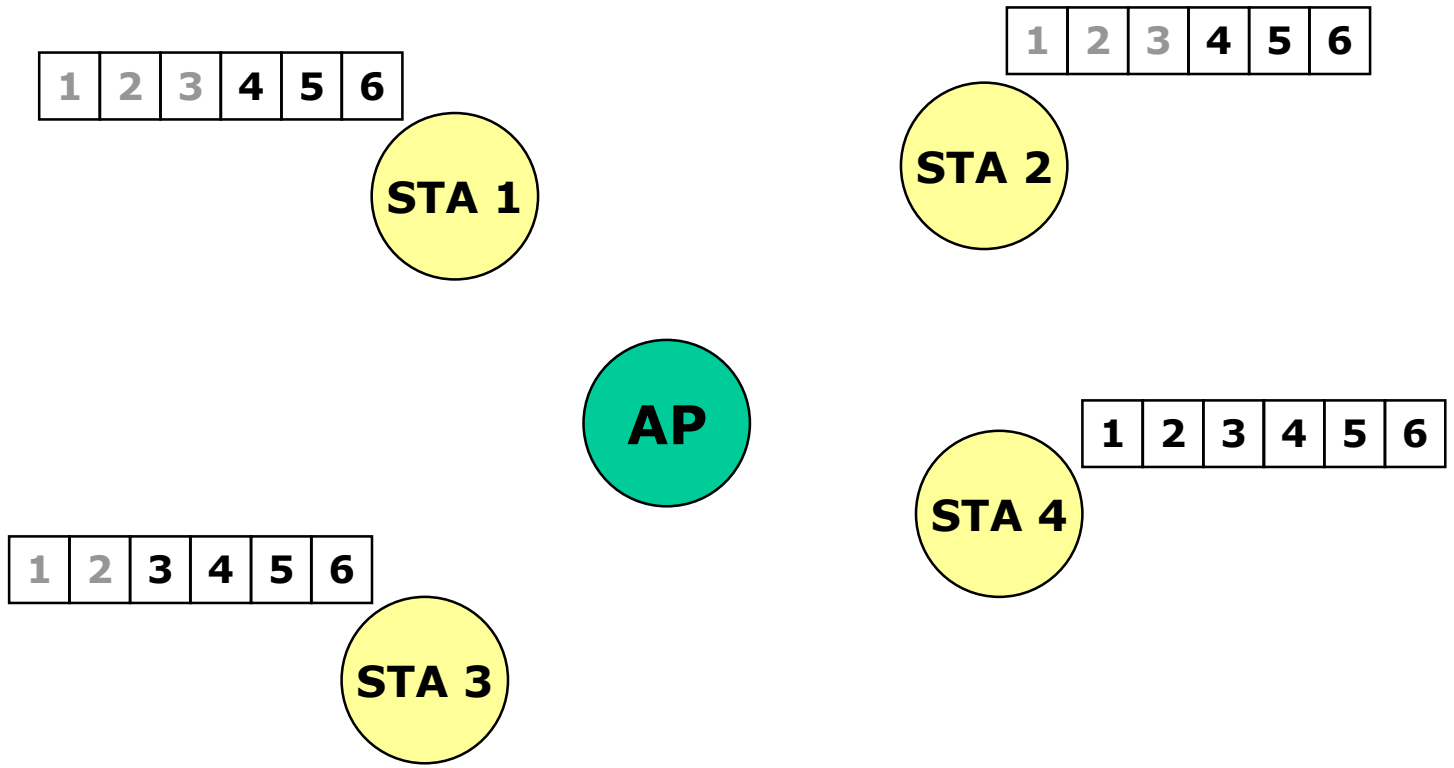

GCR Service Period

- **If one device uses power save, all multicast/broadcast traffic gets buffered until DTIM**
  - DTIM typically every $^{3}/_{10}$ second
  - Not great for video/voice
- **GCR-SP allows much smaller delays between delivery**
  - Scheduled so devices can sleep between service periods

GCR-SP

- **In GCR Request STA specifies if it does/doesn't want the AP to use GCR-SP, or "doesn't care"**
- **If AP uses GCR-SP, a Schedule element is included in the GCR Response sub-element**
  - Schedule of when these group addressed frames might be transmitted – STA must be Awake at these times
  - If Service Interval=0, frames could be transmitted at any time – STA must stay Awake (GCR-A)
- **GCR-SP frames are always concealed**
  - Because they might be transmitted before the "legacy" transmission

References

1. https://mentor.ieee.org/802.11/dcn/15/11-15-1161-02-0arc-802-11-multicast-properties.ppt
2. http://standards.ieee.org/getieee802/download/802.11-2012.pdf **(includes 802.11v amendment)**
3. https://mentor.ieee.org/802.11/dcn/15/11-15-1015-01-00ax-proxy-arp-in-802-11ax.pptx
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