

U-APSD explained

1 Scope

This document aims to explain the logics and behaviour of 802.11 power-save mechanisms and U-APSD as implemented in the Ascom i62

The document will also suggest some methods to debug any anomalies or problems with U-APSD operation.

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2 Abbreviations

AP	Access Point
EDCA	Enhanced Distributed Channel Access
QoS	Quality of Service
U-APSD	Unscheduled Automatic Power Save Delivery
WMM	Wireless MultiMedia

3 General

U-APSD is a power-save mechanism that is an optional part of the IEEE amendment 802.11e, QoS. U-APSD is also known as WMM Power Save, and the behaviour and operation is exactly the same, except for coding of some information elements.

U-APSD is working in conjunction with WMM and is tied with usage of the 4 EDCA access categories that is used to differentiate packets and their priorities.

U-APSD is very well suited for bi-directional data flows like voice.

The power savings is around 400% with Ascom i62 default settings compared to active mode, and extends the talk time from around 4 hours in active to around 16 hours in U-APSD mode with the standard battery.

The table below shows the relationship between 802.11 specifications and Wi-Fi alliance certifications programs.

Functionality	IEEE 802.11 terminology	Wi-Fi Alliance certifications
QoS mechanism	EDCA	Wireless Multi Media (WMM)
Power-Save	U-APSD	Wireless Multi Media Power-Save (WMM-PS)

4 Legacy Power management modes in 802.11

802.11 specify the use of legacy power-save operation in which two station modes are defined: Active-mode and PS-mode (Power-Save-mode).

4.1 Active mode

When the station is in active mode, all frames destined to the station are transmitted immediately from the AP to the client. The station's receiver must be turned on constantly in order to receive a frame at any time.

This power consumption in this mode is high due to the always-on receiver mode.

4.2 PS-mode

When the station is in PS-mode its receiver is turned off and can not receive any frames. The AP will temporarily buffer all frames destined to a station that is in PS-mode.

As soon as a frame is buffered in the AP, the AP will announce the presence of buffered frames to station X. This announcement is done in the AP's periodical beacon transmission. The announcement is called TIM (Traffic Indication Message).

In PS-mode, the station will wake up periodically and listen to beacons. If a beacon indicates that a frame is buffered for the station, the station will transmit a polling frame (QoS Null) to

the AP. This QoS Null data frame will release the buffered frame and the AP proceeds to transmit the frame. The station will have its receiver turned on until the frame is received.

In PS-mode, the station is free to send uplink frames to the AP at any time at its own convenience.

To make the picture more complex, the concept of DTIM period is introduced. DTIM period is just a recurring period, defined in number of beacons. At DTIM, broadcast and multicast frames are transmitted. In idle mode, the i62 is awake only at DTIM to receive broadcasts and evaluate if any buffered frames are present in the AP.

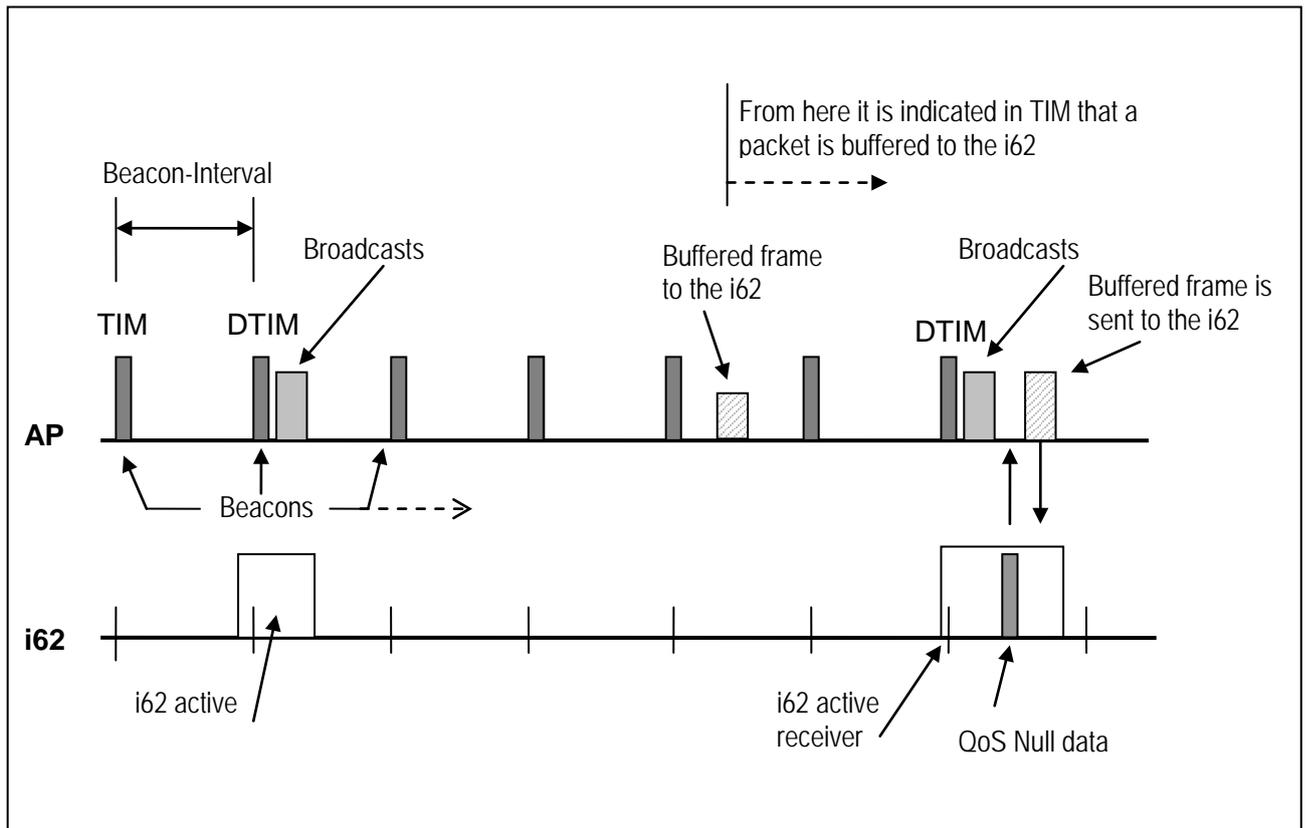


Figure 1: Example operation of stations in PS-mode

4.3 How does the AP know the station's current mode?

This is quite simple as two basic rules apply:

- 1) Stations changing Power Management mode shall inform the AP of this fact using the Power Management bits within the Frame Control field of transmitted frames.
- 2) A station shall remain in its current Power Management mode until it informs the AP of a Power Management mode change via a successful frame exchange.

5 U-APSD operation

The two Power Management modes are valid also in U-APSD mode and the AP buffers downlink frames only if the station is in PS-mode.

U-APSD is basically a polling scheme, like legacy 802.11 PS Management, but in U-APSD mode, any uplink frame acts as a polling frame and is called a "trigger frame".

The requirement for a buffered frame to be released is that the trigger frame is of the same EDCA Access Category as the buffered frame.

5.1 When is U-APSD enabled?

An AP capable of supporting automatic power save delivery (APSD) is indicating this capability through the use of the APSD subfield in the Capability Information field. If the supported U-APSD capability only is in the flavour of WMM Power Save, the capability is indicated in the QoS info field in the WMM parameter/information elements.

This information is present in Beacon, Probe Response, and (Re) Association Response management frames.

Upon association, the i62 negotiates with the AP and trigger-enable the all access categories.

5.2 U-APSD flow example

The example is based on a voice call with bi-directional flow, symmetric codec speech frames:

A call is established between two parties. In this case we assume the parties are a wireless phone (i62) and a fixed phone that resides somewhere on the LAN.

1) In the AP, a voice packet from the fixed phone is received from the distribution system (Ethernet). The packet is destined to the i62 and the AP intends to transmit the packet on the RF interface immediately.

However, the destination station (the i62) for the packet is in PS-mode and since the AP keeps track of all associated stations PS management mode, this is recognised and the packet is buffered in the AP.

2) Just after a little while, the i62 transmits a voice packet (as is done every 20 ms with default settings). This packet is transmitted within the EDCA Access Category "Voice" (which means that it is highly prioritised).

3) The AP receives the packet from the i62, forwards the packet to the distribution system (Ethernet) and recognises that the sending station has a buffered packet within the same EDCA Category "Voice" as the just received packet. The AP releases the packet and transmits the packet immediately to the i62 that now is awaiting a packet.

The procedure when an AP transmits a buffered packet due to a trigger frame is called an "Unscheduled Service Period".

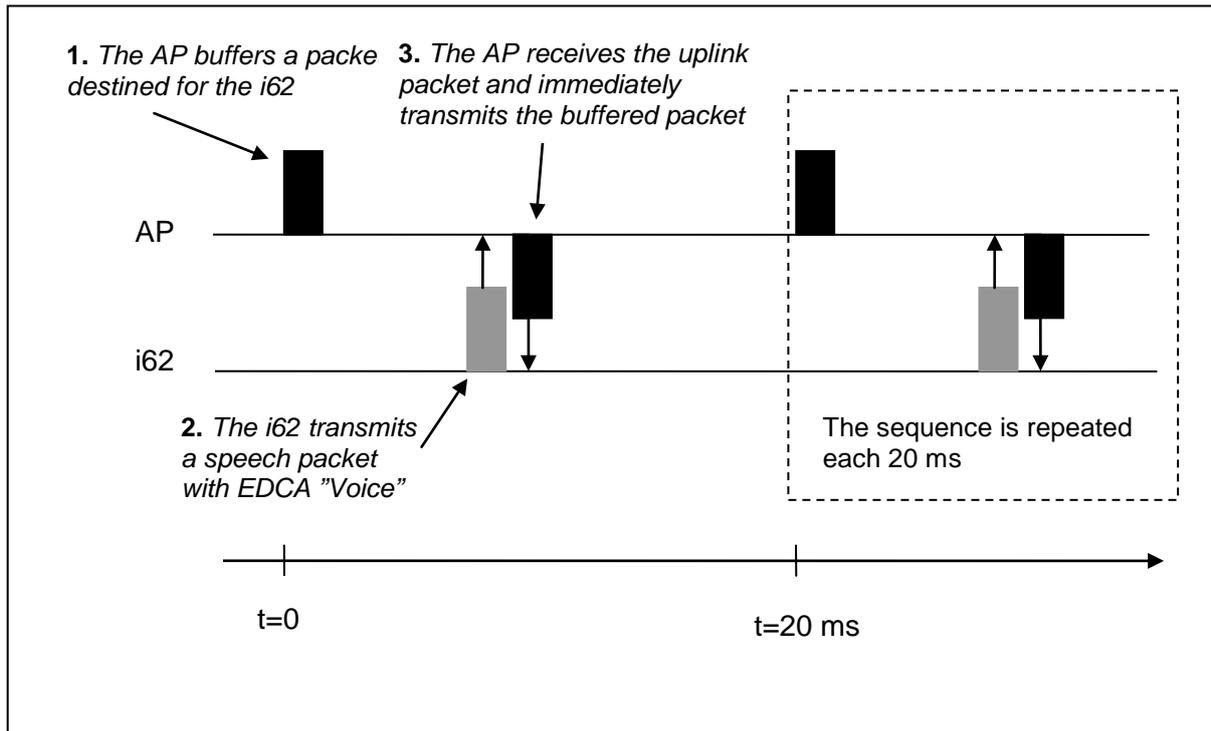


Figure 2: An U-APSD flow example

6 U-APSD troubleshooting

This section describes how to verify that U-APSD is set-up and configured correctly. U-APSD is normally an always-present feature not needing to be specially enabled. However, some WLAN infrastructure may need to tune the parameters associated with U-APSD, see the appropriate configuration notes for the infrastructure.

The screenshots are made from captures with OmniPeek protocol analyzer.

Various Access Points are used in these examples since all APs supporting this functionality will use the same information elements coding.

6.1 Does the AP support U-APSD?

First, we will determine if the AP supports U-APSD. The i62 will not use U-APSD if this capability is not indicated by the AP.

The support of U-APSD is indicated in the QoS information element, which is present in the WMM tag. The valid WMM tag we want to look at is present in beacons and probe responses.

Let's have a look
what's inside a
beacon

The screenshot shows the OmniPeek interface with a capture of several packets. Packet 13 is highlighted as an 802.11 Beacon. The packet details pane shows the following information:

- Packet Info: Flags=0x00000000 Status=0x00000000 Packet Length=111 Timestamp=15:03:09.714127000 05/02/2007 Data Rate=12.6
- 802.11 Management - Beacon
 - Timestamp: 2228121985 Microseconds
 - Beacon Interval: 100
 - Capability Info: 0000010000110001
 - SSID ID=0 SSID Len=13 SSID=CompTest80211
 - Rates= ID=1 Rates: Len=8 Rate=6.0 Mbps Rate=9.0 Mbps Rate=12.0 Mbps Rate=18.0 Mbps Rate=24.0 Mbps Rate=36.0 Mbps Rate=48.0 Mbps
 - DSPS= ID=3 DSPS: Len=1 Channel=11
 - TIM= ID=5 TIM: Len=4 DTIM Count=0 DTIM Period=5 Bitmap Offset=0 xxxx xxx. Traffic Ind.=1 ... Part Virt Bmap=0x00
 - Country ID=7 Country Len=6 Country Code=SE Starting Channel=1 Number of Channels=13 Max Tx Power (dBm)=20
 - ERP= ID=42 ERP: Len=1
 - WMM
 - Element ID: 221 WMM
 - Length: 24
 - OUI: 00-50-F2
 - OUI Type: 2
 - OUI SubType: 1 Parameter Element
 - Version: 1
 - QoS Info: 0x00000000
 - 2... WMM AP supports U-APSD
 - ... Reserved
 - ... 0000 Parameter Set Count: 0
 - Reserved: 0x00
 - Access Category - Best Effort

In this beacon, the WMM parameter element is present and contains the QoS information element. The MSB in this field indicates if U-APSD is supported!

Is the i62 signalling its use of U-APSD?

The i62 advertises its use of U-APSD and negotiates the usage of U-APSD during the association process. Let's take a look at an association process when the U-APSD is enabled in a correct way.

The packet we are interested in is the Association request

The image shows a Wireshark capture of an 802.11 Association Request packet (packet 1118). The packet list pane shows the following details for packet 1118:

Packet	Source	Destination	BSSID	Flags	C...	Sig...	Data...	802.11 Flags	Size	Delta Time	Relative Time	Protocol
1118	AscomTatec:11:AF:6E	AscomTatec:11:AF:6E	C4:10:8A:3C:F3:CA	*	11	-33	1.0	124	0.002867000	0.113598000	802.11 Assoc Req

The packet details pane shows the following information:

- 802.11 Management - Association Request
- Capability Info=0000010000100001
- Listen Interval: 8 [26-27]
- SSID ID=0 SSID Len=5 SSID=ascom
- Rates= ID=1 Rates: Len=4 Rate=1.0 Mbps Rate=2.0 Mbps Rate=5.5 Mbps Rate=11.0 Mbps
- Extended Supported Rates ID=50 Extended Supported Rates Len=8 Rate=6.0 Mbps Rate=9.0 Mbps Rate=12.0 Mbps Rate=18.0 Mbps Rate=24.0 Mbps Rate=36.0 Mbps Rate=48.0 Mbps
- HT Cap= ID=45 HT Cap: Len=26
- Vendor Specific ID=221 Vendor Specific Len=30 OUI=00-90-4C Epigram Data= (27 bytes)
- WMM
 - Element ID: 221 WMM [111]
 - Length: 7 [112]
 - OUI: 00-50-F2 Microsoft [113-115]
 - OUI Type: 2 [116]
 - OUI SubType: 0 Information Element [117]
 - Version: 1 [118]
 - QoS Info: \$00001111 [119]
 - Reserved [119 Mask 0x80]
 - Reserved [119 Mask 0x60]
 - Reserved [119 Mask 0x10]
 - Access category: Best Effort U-APSD - Enabled [119 Mask 0x08]
 - Access category: Background U-APSD - Enabled [119 Mask 0x04]
 - Access category: Video U-APSD - Enabled [119 Mask 0x02]
 - Access category: Voice U-APSD - Enabled [119 Mask 0x01]
- PCS: PCS=0xDD783FEF Calculated

The QoS information element from the i62 contains information of how U-APSD shall be used. In this frame we can see that the i62 requests all access categories to be delivery-enabled

6.2 Does the U-APSD flow work correctly?

As mentioned earlier, if an AP shall start an unscheduled service period and deliver any buffered frames, the uplink trigger frame must be of the same or higher Access Category as the buffered frame.

This means that is very important that packet classification and QoS settings are configured correctly in the AP.

All instances (i62, gateways, fixed phones etc) that might transmit a voice stream towards a wireless phone must mark the voice packets with appropriate QoS settings.

For the voice flow with U-APSD, we will look and describe the sequence for the three packets as seen in the capture below.

The first packet is an uplink voice packet sent by the i62 and acts as a trigger frame to start an unscheduled service period

The screenshot shows the OmniPeek interface with a packet capture table and a detailed view of packet 359 268. The table lists several packets, with the first one being an uplink voice packet. The detailed view shows the following fields:

- Type: \$10 Data
- Subtype: \$1000 QoS Data
- Frame Control Flags: \$00010001
 - 0... Non-strict order
 - .0... Non-Protected Frame
 - ..0... No More Data
 - ...1... Power Management - power save mode
 -0... This is not a Re-Transmission
 -0... Last or Unfragmented Frame
 -0... Not an Exit from the Distribution System
 -1... To the Distribution System
- Duration: 44 Microseconds
- BSSID: 00:14:1B:62:A2:80
- Source: 00:01:3E:10:04:66 Ascom Tataco:10:04:66
- Destination: 00:90:33:0A:03:C4 Innovaphone:0A:03:C4
- Seq Number: 1811
- Frag Number: 0
- QoS Control Field: \$0000000000000110
 - xxxxxxx x... Reserved
 -00... Ack: Normal Acknowledge
 -0... EOSF: Not End of Triggered Service Period
 -0... Reserved
 -110 UF: 6 - Voice

Annotations in the image:

- "The i62 is in PS-mode" points to the Power Management bit (1) in the Frame Control Flags.
- "The packet is in the uplink direction" points to the To DS bit (1) in the Frame Control Flags.
- "The packet is transmitted in the Access category Voice" points to the QoS Control Field (AC_VO) in the QoS Control Field.

The second packet is a downlink packet that the AP transmits immediately in response to the trigger frame.

The screenshot shows the OmniPeek interface with a packet list and a detailed view of packet 359269. The packet list shows a sequence of packets from source IP 172.20.13.191 to destination IP 172.20.15.115. The detailed view shows the following fields:

- Version: 0
- Type: \$10 Data
- Subtype: \$1000 QoS Data
- Frame Control Flags: \$00100010
 - 0... Non-strict order
 - .0... Non-Protected Frame
 - ..1... More Data
 - ...0... Power Management - active mode
 - ...0... This is not a Re-Transmission
 - ...0... Last of Unfragmented Frame
 - ...1... Exit from the Distribution System
 - ...0... Not to the Distribution System
- Duration: 44 Microseconds
- Destination: 00:01:3E:10:04:66 Ascom Tateco:10:04:66
- BSSID: 00:14:1B:62:A2:80
- Source: 00:90:33:0A:03:C4 Innovaphone:0A:03:C4
- Seq Number: 3152
- Frag Number: 0
- QoS Control Field: \$0000000000000110
 - xxxxxxx x... Reserved
 - ...0... Ack. Normal Acknowledge
 - ...0... EOSF: Not End of Triggered Service Period
 - ...0... Reserved
 - ...110 UP: 6 - Voice

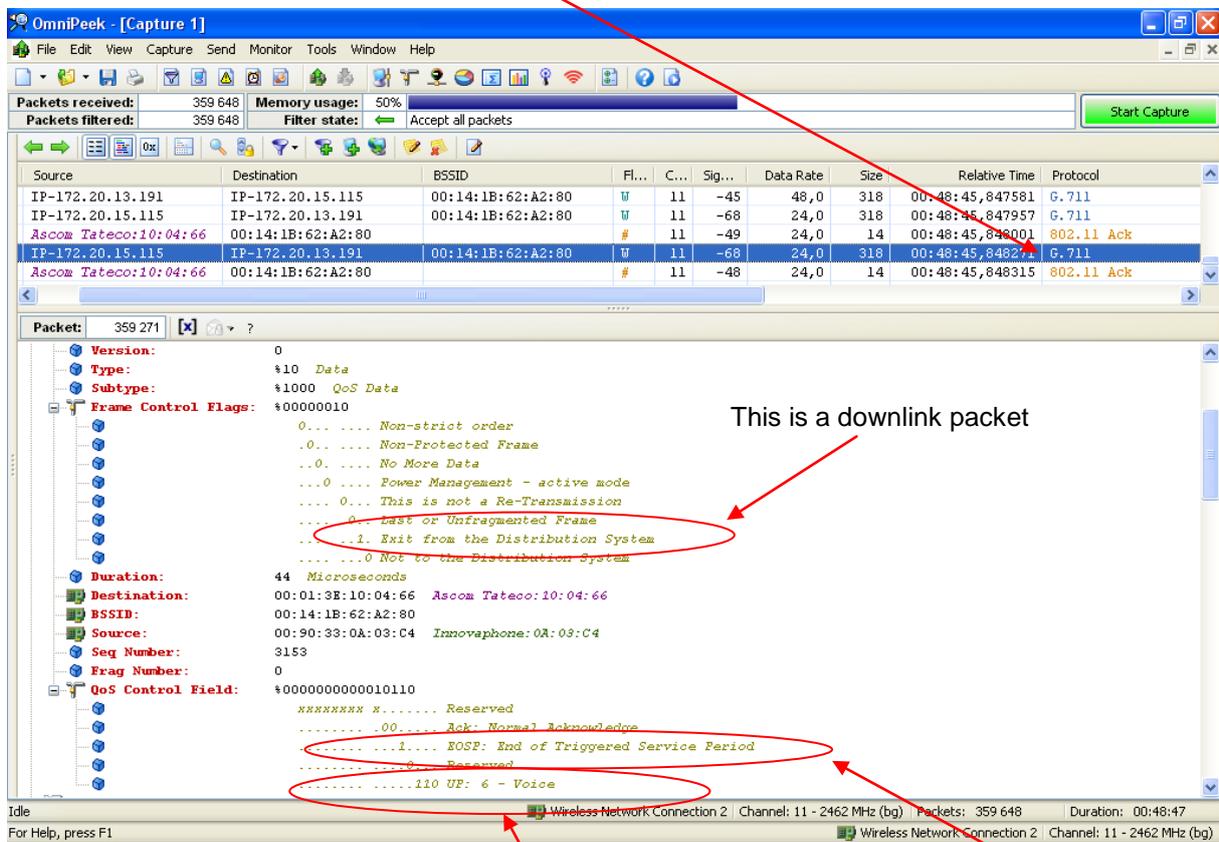
Red annotations in the image include:

- An arrow pointing from the text above to the second packet in the list.
- An arrow pointing to the text "This is a downlink packet" which points to the packet details.
- Red circles around the "Exit from the Distribution System" flag and the "EOSF: Not End of Triggered Service Period" field.
- An arrow pointing from the text below to the "UP: 6 - Voice" field.

This packet is classified correctly and transmitted by the AP in the Access category voice.

This tells the i62 that more packets are buffered and will be transmitted immediately following this packet

The third and last packet in this sequence is another buffered voice packet. Due to wired network impairments, it can be common that two voice packets will be delivered during an unscheduled service period.



This packet is classified correctly and transmitted by the AP in the Access category voice.

This tells the i62 that no more packets are buffered; this packet marks the end of the unscheduled service period.

When the i62 receives a packets that marks the end of the unscheduled service period, it shuts down the receiver and enters doze mode until the next uplink voice packet is transmitted, 20 ms later.

If no packets are buffered in the AP or if any buffered packets do not belong to the same Access category as the trigger frame, the AP will respond with a QoS Null-frame as an indication that no frames are buffered.

6.3 Symptoms of an erroneous configuration

In opposite to its predecessor, the i62 have all Access categories trigger enabled while the i75 only have the “Voice” EDCA enabled. This makes the i62 more forgiving to erroneous configurations since an uplink packet in EDCA “Voice” will trigger all lower categories. However, as the lower categories are not prioritized as high the speech quality might be degraded, especially in highly utilized systems. It is therefore important to verify that the downlink voice data packets are sent in the correct access category. Refer to section 6.2

i75 Specific troubleshooting.

As mentioned the i75 trigger enables only the “voice” Access category. It means that if the QoS priorities mapping of the downlink speech packets are not correct, the AP will not deliver the buffered speech packets in return to an uplink speech packet. Instead, the AP will advertise the presence of buffered frames in TIM and the i75 will retrieve those packets at DTIM. With i75 recommended settings (DTIM = 5) that means that buffered speech packets are retrieved every 500 ms...not good. The result will be a strange, pumping sound as the internal adaptive jitter buffer will be overflowed. The downlink speech is not perceptible in this scenario.

The uplink, on the other hand will work fine regardless of QoS configuration.

7 Document history

Rev	Date	Author	Description
PA1	2007-05-28	HSa	First draft
PA2	2011-11-09	SEKMO	Updated to match Ascom i62