DECT FORUM WHITEPAPER:

DECT Evolution

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This document aims to address some changes in the ETSI DECT standard that help increase its suitability to market spaces with stringent latency and/or reliability requirements, such as Industry 4.0 and PMSE (Program Making and Special Events).

DECT Evolution is a mid-term evolution program intended to explore the limits of TDMA/FDMA technology by adding new modulation schemes to increase the bit rate, channel coding, and reduction of latency. It is implemented as a series of improvements in the DECT CI MAC layer, Network layer and audio coding and transmission. The most relevant features of DECT Evolution are:

- Enhanced support of High-Level Modulation and introduction of Modulation and Coding Schemes (MCSs) to increase the data rate.
- New MAC service with limited delay introducing handover with slot position tolerance to give more options to change the channel in highly occupied areas.
- Improved procedures for double simplex bearers to decrease latency and allow asymmetric connections.
- Optimization of MAC control messages to handle the newly introduced slot structures and modulations.
- Support of multiple Data Link Control LU instances per call to provide flexible user data and user control handling.
- Support of multiple U-plane endpoints per connection.
- Support of combinations of slots and combinations of modulation states in multi-bearer connections.
- New improved LC3plus audio codec for narrowband, wideband, super-wideband and full-band voice services.

Two important improvements will be discussed. Both features are covered as part of DECT Evolution and are referred to as Ultra Reliable Low Latency Communication (URLLC) and Low Complexity Communication Codec (LC3plus).

URLLC

The upcoming need to support more stringent latency and reliability requirements for Industry 4.0 and PMSE (Program Making and Special Events) led to the introduction of DECT URLLC (Ultra Reliable Low Latency Communication).

A further reduction of latency and an increase of reliability realized with DECT Evolution is beneficial in several use case scenarios:

- A wireless game controller, not providing sufficiently low latency and reliability, will frustrate the user.
- A wireless public address system used to amplify voices or musical instruments will transfer latency into the well-known "echo effect", making fluent speech, singing or playing an instrument almost impossible.
- Wireless man-to-machine and machine-to-machine interfaces require low latency and high quality of service to support safe operation.

Low Latency

DECT, traditionally, has strong inherent benefits that set it apart from other wireless technologies, notably its dedicated 1.9GHz frequency band (so no overcrowding issues such as in e.g. 2.4GHz) and low latency (typically ~10-15ms for streaming applications). In order to further underscore these benefits, URLLC will improve the DECT latency to below 5ms and further increase reliability, meeting the present and future market demands.

To maintain optimum coexistence with legacy DECT, the basic 10ms frame period is retained. The lower latency supported under URLLC is achieved by defining sub-frames within the 10ms main frame period. This is depicted in Table 1 below.

Different shades of grey are used to indicate the length of the sub-frames within the 10ms standard frame to achieve lower latency. Another interesting figure to

Slot#	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
	Standard DECT downlink												Standard DECT uplink											
1+1	Cntrl	Audio																						
1+2	Cntrl	Audio												Audio										
1+3	Cntrl	Audio								Audio								Audio						
1+4	Cntrl	Audio						Audio						Audio						Audio				
1+6	Cntrl	Audio				Audio				Audio				Audio				Audio				Audio		
1+8	Cntrl	Audio			Audio			Audio			Audio			Audio			Audio			Audio			Audio	
1+12	Cntrl	Audio		Audio		Audio		Audio		Audio		Audio		Audio		Audio		Audio		Audio		Audio		Audio

Table 1: Slot configuration for different sub-frames.

Number of Up-/Downlink slots	Slot allocation	Latency [ms]	Downlink Data-rates [kbps]		
			GFSK	DQPSK	D8PSK
1+1	FP- slot + 1*PP slots	10.42	32	64	96
1+2	FP- slot + 2*PP slots	5.42	64	128	192
1+3	FP- slot + 3* PP slots	3.75	96	192	288
1+4	FP- slot + 4*PP slots	2.92	128	256	384
1+6	FP- slot + 6*PP slots	2.08	192	384	576
1+8	FP- slot + 8*PP slots	1.67	256	512	768
1+12	FP- slot + 12*PP slots	1.25	384	768	1152

Table 2: Slot allocation latency and data rates of different sub-frames.

note is the increased number of portable parts that can simultaneously connect to a fixed part using these scenarios.

The resulting latency per configuration is determined by the length of the sub-frame period, added with one slot length and can be found in Table 2 above.

Note that the latency numbers are for the DECT link only. Any processing delay (e.g. from a CODEC) is not included. The corresponding data-rates are a function of the number of slots used for the link, combined with the modulation method. In this example, three modulation methods (as supported in the DECT standard) are listed, i.e. GFSK, DQPSK and D8PSK.

In Table 2, FP stands for 'Fixed Part' and PP denotes 'Portable Part'. Using Wi-Fi terminology, these can respectively be regarded as 'Access Point' and 'Wireless Client. The summary of this important development is that latency of 1,25ms is possible in certain use cases, making it very interesting for industrial IoT-like process automation.

Reliability

As mentioned already in the introduction, DECT operates in a dedicated frequency band. No other technology is allowed in this frequency band, so, in Europe, DECT is protected against interference from other technologies inside the band. The main limitation under consideration regarding data reliability is interference from other DECT systems. This is the case when multiple DECT FP's are used in the same environment. The following section is less relevant in case of single DECT FP deployment, in which case reliability is inherently ensured.

ETSI EN 301 406 specifies a reference bit error rate better than 10ppm and a reference frame error rate better than 500ppm for inputs powers of -73dBm or greater. Typical applications already largely outperform this and far exceed the 5G requirements when not considering interference from other DECT systems. The better than -90dBm receiver sensitivity of today's DECT systems provides a significant range increase, which helps home and enterprise systems to cover wider areas with less base stations.

Network system simulations have been performed of typical DECT systems. These include the effects of timing misalignment, radio propagation and selectivity, among others. These simulations have focused on the DECT-DECT interference aspects, especially in user-dense scenarios to define data reliability and throughput.

These simulations have pointed out that excellent data reliability is maintained, provided that the FP's are synchronized. With synchronized timing it is ensured that one system's transmissions don't drift into the transmissions of another system, causing data collisions. It has also been confirmed in actual implementations that multi-cell DECT-base systems can meet the reliability requirements, provided they are synchronized.

On top of supporting synchronization, Forward Error Correction (FEC) and other means of redundant data transmission may be considered to further improve data reliability, to make synchronized systems even more robust towards unsynchronized DECT systems in range.

LC3plus

With the introduction of the 3GPP Enhanced Voice Service (EVS) in 2014, the mobile voice communication was enriched with the Super Wide Band (SWB) audio quality. However, this technical development came along with a significant increase in computational complexity and memory demands, limiting deployment to relatively powerful mobile phones. LC3plus aims to provide the low complexity counterpart of EVS in order to make SWB also available on low-cost terminals such as used in DECT systems. The codec allows perfect interoperability between mobile and other networks by means of transcoding and fits well to the requirements of DECT terminal equipment in terms of complexity. Due to the codec's flexible design the applications are not limited to voice services but can be extended to high quality music streaming as well.

Modes of operation

The LC3plus codec can operate at highly flexible modes, which are summarized in Table 3 opposite. It supports coding of speech and audio for several audio

Feature	Supported Range
Frame duration	2.5ms, 5ms and 10ms (2.72ms, 5.44ms, 10.88ms @ 44.1 kHz)
Look ahead delay	2.5ms (2.7ms @ 44.1kHz)
Total algorithmic delay	Frame duration + Look ahead delay = 5ms, 7.5ms, and 12.5ms (for sampling rates other than 44.1kHz)
Supported sampling rates	8, 16, 24, 32, 44.1 and 48kHz
Audio bandwidth	Max. 20kHz for 48kHz
Supported Bit rate	20 to 400 bytes per frame and channel, e.g. 16 to 320kbit/s per channel for 10ms frame length and 48kHz sampling rate
Supported bits per audio sample	No restriction by the algorithm, however optimized for 16, 24, 32 bit depth input

Table 3: Feature summary LC3plus.

Use case (high level)		Availability	Cycle time	Typical payload size	# of devices	Typical service area
Motion control	Printing machine	>99.9999%	< 2 ms	20 bytes	>100	100 m x 100 m x 30 m
	Machine tool	>99.9999%	< 0.5 ms	50 bytes	~20	15 m x 15 m x 3 m
	Packaging machine	>99.9999%	< 1 ms	40 bytes	~50	10 m x 5 m x 3 m
Mobile robots	Cooperative motion control	>99.9999%	1 ms	40-250 bytes	100	< 1 km^2
	Video-operated remote control	>99.9999%	10 – 100 ms	15 – 150 kbytes	100	< 1 km^2
Mobile control panels with safety functions	Assembly robots or milling machines	>99.9999%	4-8 ms	40-250 bytes	4	10 m x 10 m
	Mobile cranes	>99.9999%	12 ms	40-250 bytes	2	40 m x 60 m
Process automation (process monitoring)		>99.99%	> 50 ms	Varies	10000 devices per km^2	

Source: ZVEI

Table 4: Industrial Use cases.

bandwidths, using the sampling frequencies 8 kHz, 16 kHz, 24 kHz, 32 kHz or 48 kHz. The LC3plus codec may also be used for streaming audio and therefore also supports CD sampling rate (44.1 kHz). It supports encoding and decoding using either a 2.5 ms, 5 ms or 10 ms frame duration. A large number of compressed frame sizes from 20 bytes to 400 bytes can be configured.

Similarly, the inherent flexibility brought by DECT Evolution offers system architects a range of supported frame sizes, sampling rates and audio bandwidth, enabling new and upgraded product feature sets in areas such as broadcasting, live recording, as well as audio streaming for conferencing systems and wireless loudspeakers.

Applications that could potentially profit from DECT Evolution

DECT Evolution is part of the current DECT standard and enables manufacturers and system integrators to develop applications that can be implemented using the current DECT GFSK interface. This “evolution path” was already foreseen in the DECT base standard and considered in the MAC and PHY layers. Implementations are already available in silicon. This improvement in the functional scope allows DECT (Evolution) systems to address a range of applications, which were hitherto out of scope. Industrial wireless is one such area. It is characterized by its stringent requirements for reliability and (low)latency, as well as Quality of Service (Traffic Classification and Prioritization) and device density. The 5G Industrial Use case table (Table 4. above) from ZVEI shows some typical industrial use cases and their requirements. DECT Evolution already fulfills many of the key requirements mentioned in several such use cases. For instance, when considering Range, Density, Latency and System Availability, Process automation would profit greatly from this upgrade of the technology.

Other segments like healthcare (Telecare, remote monitoring) would also benefit from this improved latency and data bandwidth.

Conclusion

DECT is a proven reliable wireless technology. DECT Evolution brings a host of improvements to the technology based on currently available silicon. With the URLLC and LC3plus additions to the DECT ETSI standard, significant improvements can be achieved in terms of data reliability, latency and audio performance. This is especially beneficial for well-known applications in PMSE (Program Making and Special Events), but also in healthcare, and potentially new applications areas such as industrial automation. DECT Evolution was conceived to optimize the potential of legacy DECT, remaining flexible, backward compatible and competitive, and open the door to a wide range of application fields like:

- Call centers and offices with high density of DECT headsets
- Low latency game controllers
- Critical man-to-machine and machine-to-machine interfaces in Industry 4.0
- Controller and wireless sensors for augmented reality
- Smart Home and building automation
- Process automation
- Connected healthcare sensors
- Mobile robots
- … and much more