DEFENDING WORLD SECURITY

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Security and Communication Solutions

Alina Alexandra FLOREA, *Research Engineer – PhD Student.*

Multi-layer Realistic Voice Capacity Evaluation in LTE Rel. 9 and Performance Comparison with PMR and GSM

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Summary

1. Purpose of the study,

- why LTE from a PMR perspective?

2. LTE, towards 4G,

- existent solutions for voice transmission,
- transmission system description.

3. LTE voice capacity evaluation

- proposed system for a PMR use case,
- results.

4. Conclusions.

Purpose of the study,
why LTE from a PMR perspective?

- **PMR = Private or Professional Mobile Radio**
  - public safety, critical situations (emergencies, disasters), industrial use,
  - 2G: digital narrowband (10 to 25 kHz), trunked allocation strategy, voice transmission using circuit-switched concepts.
    - **TETRA** (Terrestrial Trunked Radio) – ETSI,
    - **Tetrapol** – EADS proprietary.
  - 3G: **TEDS** (TETRA Enhanced Data System).

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Purpose of the study, why LTE from a PMR perspective?

- **What is a PMR perspective?**
  - frequencies used in the **UHF**: 400 MHz (Europe) and 700MHz (USA), with reduced dedicated bandwidths => ***analysis for the smallest LTE BW (1.4 to 5 MHz),***
  - voice communications must be available in critical situations, low throughput voice transmissions are privileged for an enhanced spectrum efficiency => **low bit rate voice coders (~ 5 to 6 kbps)** => ***use of AMBE 2.45 kbps,***
  - in future 4G networks, **voice communications are an absolute necessity**, with an enhanced spectrum efficiency!

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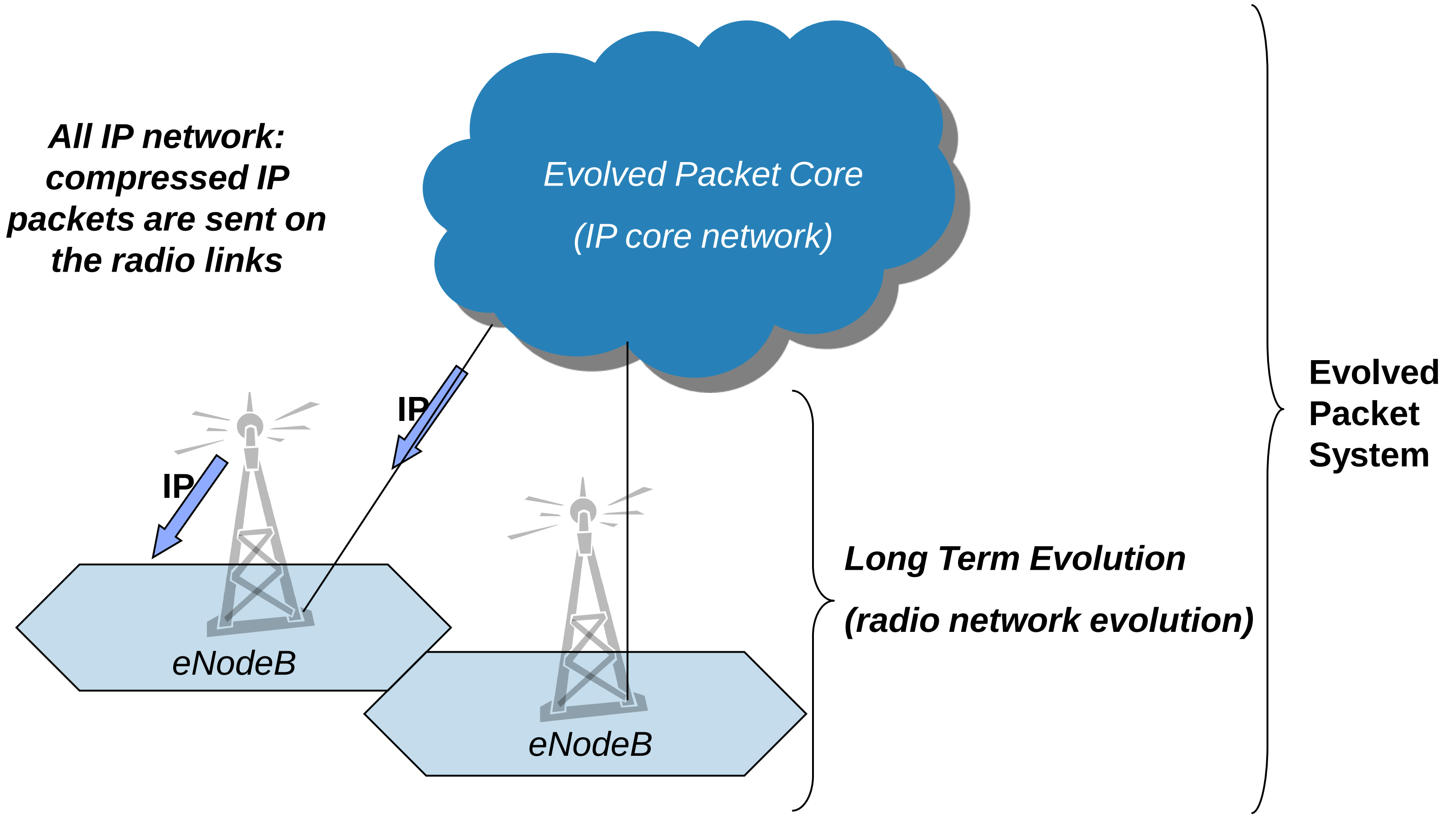
LTE, towards 4G

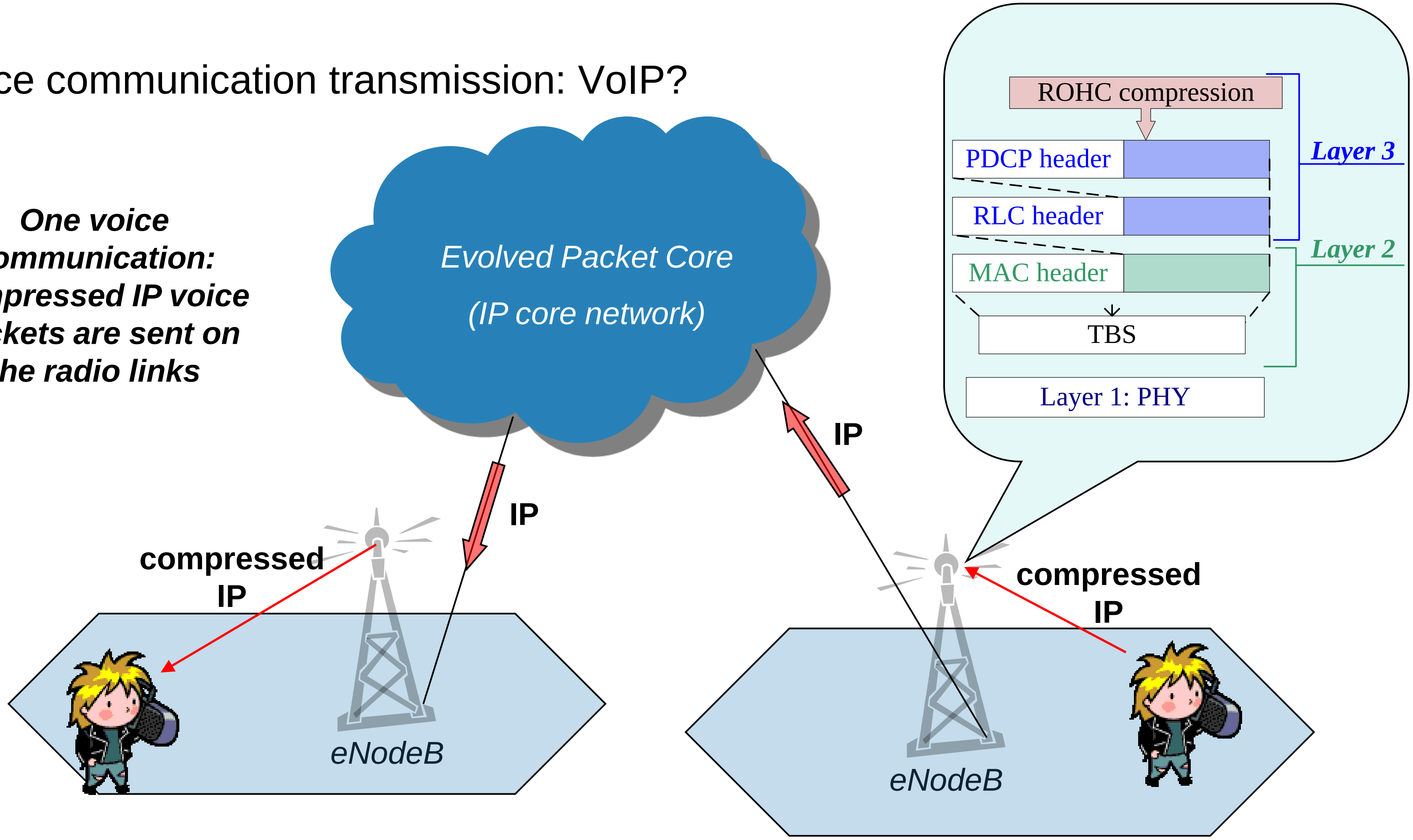
- 3GPP standards



LTE, towards 4G

- Voice communication transmission: VoIP?

One voice communication: compressed IP voice packets are sent on the radio links



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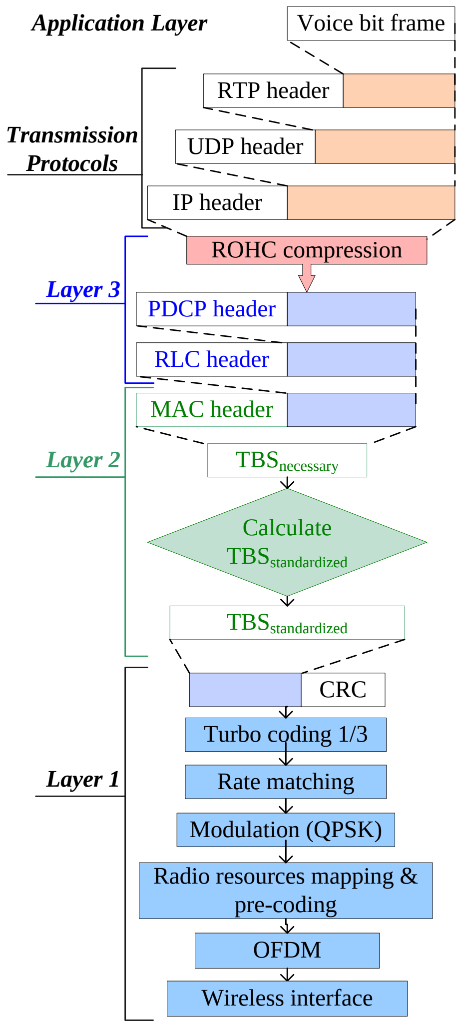
LTE, towards 4G,
existent solutions for voice transmission

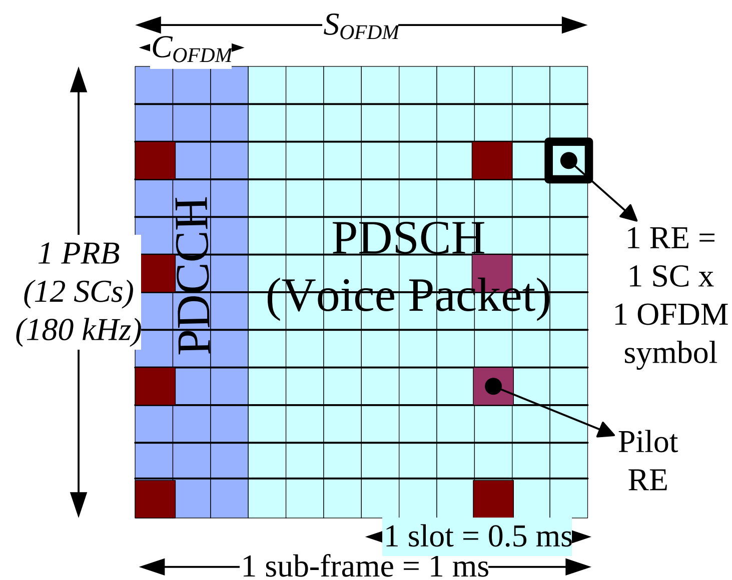
- Envisaged solution for voice communications: VoIP ?
- What is the real LTE efficiency for voice communications?
- Literature:
  - voice communications through the protocol stack
    - RLC (Radio Link Control) protocol: Unacknowledged Mode,
    - ROHC protocol compresses up to 42 % of the overhead => 3 bytes,
  - LTE spectral efficiency considering PHY key features: scheduling, CQI, MIMO, large deployment bandwidhts (10 MHz), carrier frequency 2 GHz.
- 3GPP supported solutions:
  - CS (circuit switched) fallback,
  - MMTel (IP multimedia subsystem - IMS - telephony),
  - SRVCC (IMS telephony with handover to CS domain).
- 3GPP not supported solutions:
  - VoLGA (voice over LTE generic access),
  - internet-based voice services.

LTE, towards 4G,
transmission system description.



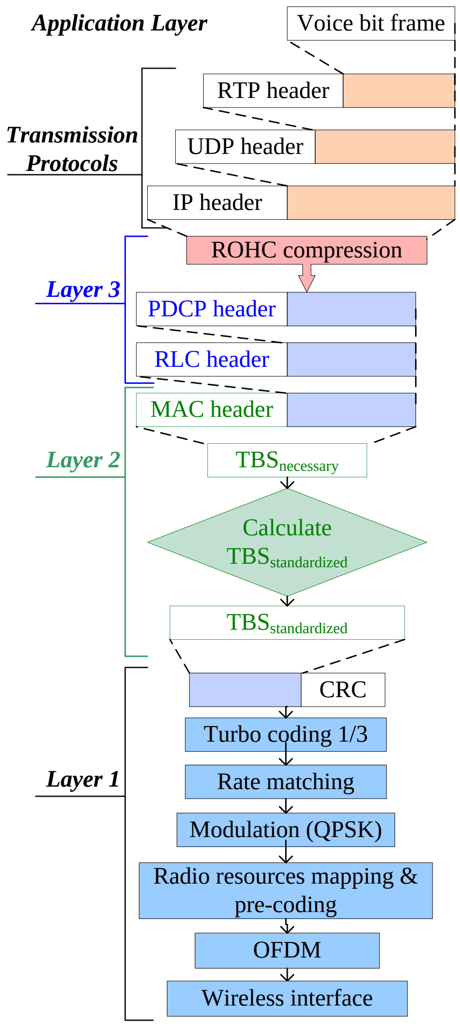
$$\min \left| R_{scheduled} - \frac{TBS_{standardized} + N_{CRC}}{N_{ch}} \right|$$

$$N_{ch} = N_{REs/PRB} \times N_{PRB}$$



LTE voice capacity evaluation

proposed system for a PMR use case



1) $P_{voice} = R_{vocoder} * T_{voice}$.

2) $TBS_{necessary} = P_{voice} + H_{protocols}$.

3) $N_{REs/PRB} = 12 * (S_{OFDM} - C_{OFDM}) - N_{pilots}$.

4) For all $i=1$ to N_{BW} $\min\left(TBS(i) - TBS_{necessary}\right) > 0$

5) Normalize all coding rates

$$N_{ch}(i) = N_{RE/PRB} \times i$$

$$\delta_{rate}(i) = \left| R_{scheduled} - \frac{TBS(i) + N_{CRC}}{N_{ch}(i)} \right|$$

$$R_{normalized}(i) = \frac{\delta_{rate}(i)}{\max(\delta_{rate})}$$

6) Normalize TBS values $TBS_{normalized}(i) = \dfrac{TBS(i) - TBS_{necessary}}{TBS(i) * \max(TBS)}$

7) Minimum TBS value closest to $TBS_{necessary}$

$$TBS_{standardized} = TBS\left(index\left\{\min(R_{normalized} + TBS_{normalized})\right\}\right)$$

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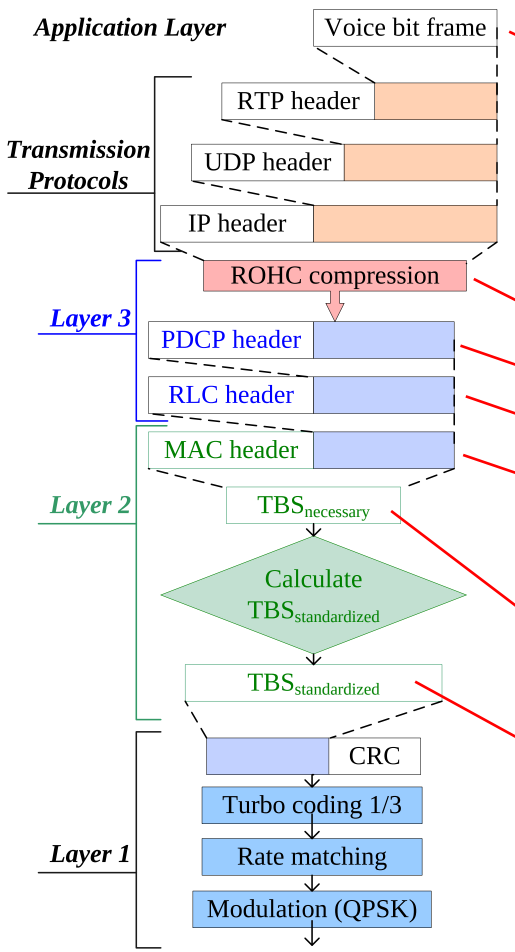
LTE voice capacity evaluation

results

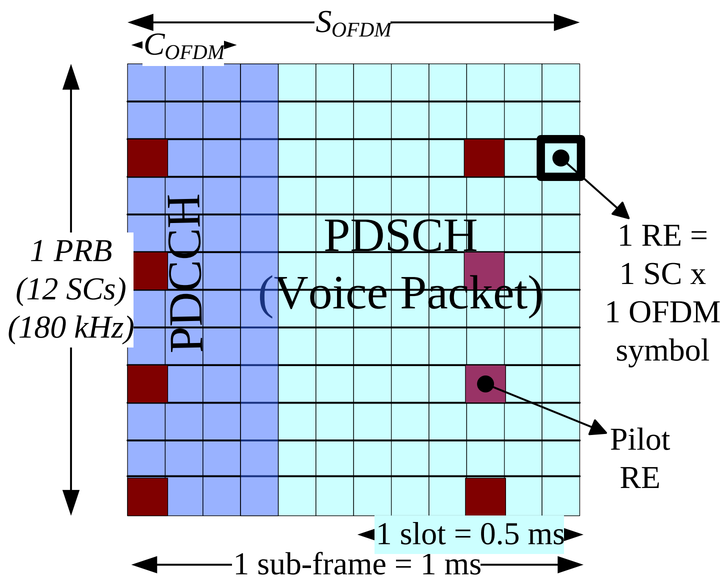


LTE DL Voice Capacity Evaluation Results.

System parameters	*Computed values*	*Realistic values*	*Ideal values*
Voice encoder AMBE	$R_{vocoder}$	2450 bps	
	T_{voice}	20 ms	
	P_{voice}	49 bits	
Transmission protocols	RTP + UDP + IP	40 bytes	40 bytes
PDCP ROHC compression		3 bytes	1 byte
PDCP header		1 byte	0
RLC header		1 byte	0
MAC header		1 byte	0
Higher layer overhead	$H_{protocols}$	6 bytes	1 byte
Necessary LTE TBS	$TBS_{necessary}$	97 bits	57 bits
Overhead percentage	$H/TBS_{necessary}$	49.5 %	14 %
TBS for QPSK 1/3	$TBS_{standardized}$	104 bits	72 bits
PHY CRC	N_{CRC}	24 bits	0 bits

LTE voice capacity evaluation

results



LTE DL Voice Capacity Evaluation Results.				
System parameters		***Computed values***	***Realistic values***	***Ideal values***
LTE DL S_{OFDM}=12; N_{pilots}=8; (PSS, SSS, PBCH not considered)	**1,4 MHz C_{OFDM}=4**	N_{BW}	**6**	
		N_{ch}	**336**	**168**
		R_{audio}	**0,15**	**0,29**
		R_{layer_1}	**0,38**	**0,43**
		N_{PRB}	**2**	**1**
		Number users/ sub-frame	***3***	***6***
		Number users/20 ms period	***60***	***120***

$$R_{audio} = \frac{TBS_{necessary} - H_{protocols}}{N_{ch}}$$

$$R_{layer\_1} = \frac{TBS_{standardized} + N_{CRC}}{N_{ch}}$$

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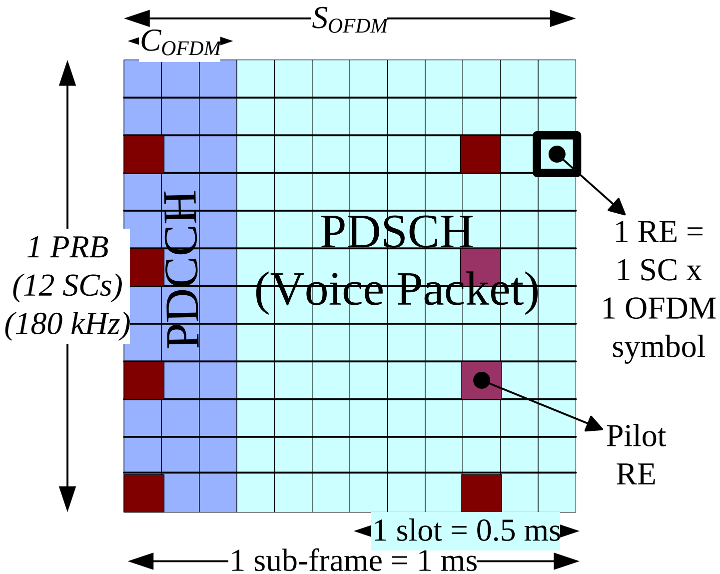
LTE voice capacity evaluation

results

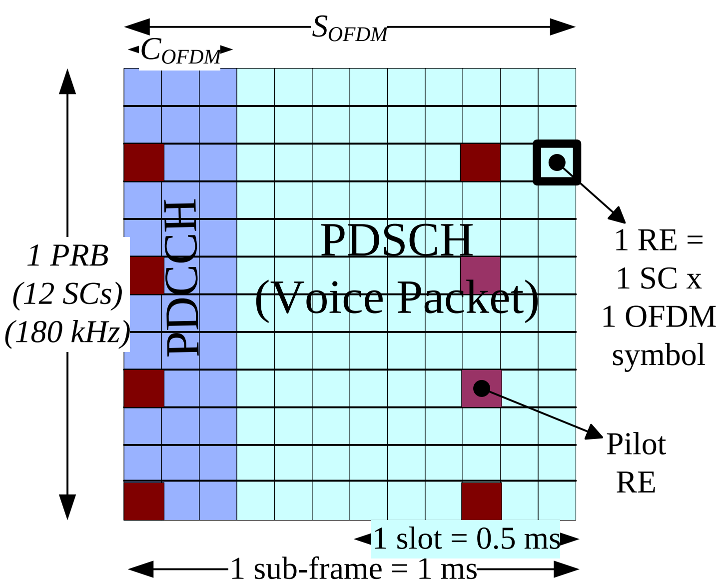


LTE DL Voice Capacity Evaluation Results.				
System parameters		*Computed values*	*Realistic values*	*Ideal values*
LTE DL S_{OFDM}=12; N_{pilots}=8; (PSS, SSS, PBCH not considered)	**3 MHz C_{OFDM}=3**	N_{BW}	**15**	
		N_{ch}	**384**	**192**
		R_{audio}	**0,13**	**0,26**
		R_{layer_1}	**0,33**	**0,38**
		N_{PRB}	**2**	**1**
		Number users/ sub-frame	*7*	*15*
		Number users/20 ms period	***140***	***300***

$$R_{audio} = \frac{TBS_{necessary} - H_{protocols}}{N_{ch}}$$

$$R_{layer\_1} = \frac{TBS_{standardized} + N_{CRC}}{N_{ch}}$$

LTE voice capacity evaluation
results



LTE DL Voice Capacity Evaluation Results.				
System parameters		***Computed values***	***Realistic values***	***Ideal values***
LTE DL S_{OFDM}=12; N_{pilots}=8; (PSS, SSS, PBCH not considered)	**5 MHz C_{OFDM}=3**	N_{BW}	**25**	
		N_{ch}	**384**	**192**
		R_{audio}	**0,13**	**0,26**
		R_{layer_1}	**0,33**	**0,38**
		N_{PRB}	**2**	**1**
		Number users/ sub-frame	***12***	***25***
		Number users/20 ms period	***240***	***500***

$$R_{audio} = \frac{TBS_{necessary} - H_{protocols}}{N_{ch}}$$

$$R_{layer\_1} = \frac{TBS_{s\tan dardized} + N_{CRC}}{N_{ch}}$$

LTE voice capacity evaluation

results

PMR and GSM Performances Results.				
Technology	**TETRA**	**TETRAPOL 10kHz**	**TETRAPOL 12,5 kHz**	**GSM 900**
Channel δ_f	**25 kHz**	**10 kHz**	**12,5 kHz**	**200 kHz**
TDMA	**4**	**1**	**1**	**8**
Number communications/ δ_f	**4**	**1**	**1**	**8**
Number communications/ $\Delta_{f\text{-}BW}$	**224**	**140**	**112**	**56**
Reuse factor	**16**	**12**	**12**	**9**
Communications/ $\Delta_{f\text{-}BW}$ /cell, $C_{BW\text{-}cell}$	**14**	**11,66**	**9,33**	**6,22**
Voice codec bit rate, $R_{vocoder}$	**ACELP 4,6 kbps**	**RPCELP 6 kbps**	**RPCELP 6 kbps**	**AMR 12,2 kbps**
Voice spectral efficiency, SE_{voice}	**0,046 bits/s/Hz/cell**	**0,05 bits/s/Hz/cell**	**0,04 bits/s/Hz/cell**	**0,054 bits/s/Hz/cell**

LTE voice capacity evaluation

results

LTE Performances Comparison Results with PMR and GSM.				
Technology	**LTE (QPSK 1/3)**	**LTE (QPSK 1/3)**	**LTE (QPSK 1/3)**	**LTE (QPSK 1/3)**
Channel δ_f	**2x180 kHz**	**4x180 kHz**	**4x180 kHz**	**6x180 kHz**
TDMA	**20**	**30**	**20**	**20**
Number communications/ δ_f	**20**	**30**	**20**	**20**
Number communications/$\Delta_{f\text{-}BW}$	**60**	**30**	**20**	**20**
Reuse factor	**1**	**1**	**1**	**1**
Communications/ $\Delta_{f\text{-}BW}$ /cell, $C_{BW\text{-}cell}$	**60**	**30**	**20**	**20**
Voice codec bit rate, $R_{vocoder}$	**AMBE 2,45 kbps**	**ACELP 4,6 kbps**	**RPCELP 6 kbps**	**AMR 12,2 kbps**
Voice spectral efficiency, SE_{voice}	**0,105 bits/s/Hz/cell**	**0,099 bits/s/Hz/cell**	**0,086 bits/s/Hz/cell**	**0,174 bits/s/Hz/cell**

Our estimation for future PMR deployements

TETRA ACELP = 0.046 bits/s/Hz/cell

TETRAPOL RPCELP = 0.04 to 0.05 bits/s/Hz/cell

GSM AMR = 0.054 bits/s/Hz/cell

Conclusions

- The higher layer's overhead and the physical layer's CRC may represent more than 50 % of the total frame size for an average ROHC compression.
- By adjusting the overhead to lower values closer to "ideal" percentages, the LTE capacity can approach its double.
- LTE is not yet optimised for small throughputs. The TBS choice is limited.
- Radio resources allocation strategy is not optimized, a minimum of one PRB pair must be reserved for each user (large when using a very low bit rate voice communications).
- Air frame overhead: the performances may be restrained because of a limited PDCCH capacity. Persistent or semi-persistent allocation allows one PDCCH field to reserve user resources for a certain number of incoming sub-frames.
- The spectral efficiency of LTE is hardly the double of that of PMR and GSM.

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Thank you!