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Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

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Introduction

This TR collects the work done under the Study Item "LTE Coverage Enhancements" [2].

1 Scope

The scope of this study item is given in [2].

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

[1] TR 21.905: "Vocabulary for 3GPP Specifications".

[2] RP-111359: Study Item Description for LTE Coverage Enhancements.

[3] R1-113619: Email Discussion Summary on Coverage Enhancements SI.

[4] R1-120008: Email Discussion Summary on Coverage Issues Identification.

[5] R1-122130: TTI bundling enhancements details for PUSCH medium data rate.

[6] R1-122506: Details of possible TTI bundling enhancements for coverage enhancement.

[7] R1-122013: On TTI bundling enhancements.

[8] R1-122641: Discussion on TTI bundling enhancements for PUSCH medium data rate coverage improvement.

[9] R1-122150: Analysis on TTI bundling enhancement for medium rate PUSCH,

[10] R1-122433: Coverage enhancements for VoIP and medium data rate.

[11] R1-122129: TTI bundling enhancements details for UL VoIP.

[12] R1-122640: Discussion on TTI bundling enhancements for PUSCH VoIP coverage improvement.

[13] R1-122149: Analysis on TTI bundling enhancement for UL VoIP.

[14] R1-122566: Link-level evaluation results for improved LTE UL VoIP coverage.

[15] R1-122719: Coverage enhancement for TTI bundling.

[16] R1-121005: Further discussion on coverage enhancement.

[17] R1-121110: Evaluation on coverage enhancement.

[18] R1-122805: Coverage enhancements for medium data rate and VoIP.

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

3.2 Symbols

For the purposes of the present document, the following symbols apply:

<symbol> <Explanation>

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

4 Objectives

This document captures the outcome of the RAN WG1 study about LTE coverage enhancements. This study aims at identifying potential coverage issues, and to investigate associated solutions. The detailed objectives of this study are described in [2].

5 Identification of Coverage Issues

5.1 Scope, Methodology, and Assumptions

5.1.1 Scope of the study

The following scope is defined for the identification of coverage issues, by taking coverage imbalance into account [3].

- First priority is identifying the limiting channel(s)/direction between the various LTE data and control channels in UL and DL.
  - The following services are considered: VoIP, medium data rate.
- The following other aspects can be studied with second priority:
  - Identifying the MCL of the minimum UL data rate for LTE;
  - Assessing the coverage of UMTS Rel-99 channels for comparison reference (especially for CS voice).
- Once the limiting channels are identified, study the possibility to enhance their coverage
  - Ideal enhancement target is to bring the limiting channels to a similar coverage as other channels.

5.1.2 Evaluation Methodology

The identification of coverage issues uses the MCL (Maximum Coupling Loss) methodology, defined as follows.

The coupling loss is defined as the total long-term channel loss over the link between the UE antenna ports and the eNodeB antenna ports, and includes in practice antenna gains, path loss, shadowing, body loss, etc. The maximum coupling loss (MCL) is the limit value of the coupling loss at which the service can be delivered, and therefore defines the coverage of the service. The MCL is independent of the carrier frequency. It is defined in the UL and DL as:

- UL MCL = UL Max Tx power - eNB Sensitivity
- DL MCL = DL Max Tx power - UE Sensitivity

The MCL is evaluated via link budget analysis (supported by link level simulations). The proposed MCL calculation template is given in following table:

Table 5-1: MCL calculation template

Physical channel name	Value
Transmitter	
(1) Tx power (dBm)	
Receiver	
(2) Thermal noise density (dBm/Hz)	

(3) Receiver noise figure (dB)	
(4) Interference margin (dB)	
(5) Occupied channel bandwidth (Hz)	
(6) Effective noise power = (2) + (3) + (4) + 10 log(5) (dBm)	
(7) Required SINR (dB)	
(8) Receiver sensitivity = (6) + (7) (dBm)	
(9) MCL = (1) – (8) (dB)	

The Rel-8/9/10 features should be considered for coverage issues identification. The impact of the features, such as HARQ, PUSCH hopping, TTI bundling, Beamforming, etc. is to be evaluated with link level simulations and included in the required SINR for the respective channel.

Solutions currently investigated in Rel-11 should not be part of the study on identification of imbalances or coverage issues, but could be considered as part of the potential solutions.

5.1.3 Evaluation Assumptions

The evaluation assumptions for the identification of coverage issues are captured in the tables below.

5.1.3.1 General parameters

Table 5-2: General parameters for coverage issues identification

Parameters	**LTE/LTE-A**	**UMTS** (for voice service comparison only)
Services and bit rates	• Service 1: VoIP (DL 12.2 kbps, UL 12.2 kbps) • Service 2: Web browsing (DL 1Mbps, UL 384kbps)	• Service 1: CS voice (DL 12.2 kbps, UL 12.2 kbps)
System bandwidth	10 MHz	5 MHz
UE Tx power	23 dBm	23 dBm
DL Tx power	46 dBm	43 dBm
Antenna configuration eNB	• 2tx, 2rx (for service 1 and service 2) • 8tx, 8rx (for service 2)	• 1tx, 2rx
Antenna configuration UE	2rx, 1tx	2rx, 1tx
eNB receiver noise figure	5 dB	5 dB
UE receiver noise figure	9 dB	9 dB
Doppler spread	7.2 Hz	7.2 Hz
Radio channel	[SCME, ePA], 3km/h	[SCM, PA], 3km/h
Thermal noise PSD	-174 dBm/Hz	-174 dBm/Hz

Note that for voice service comparison, the same band for LTE/LTE-A and UMTS is assumed.

For the value of interference margin, 0dB is mandatory. Additional value is left to the companies to decide and should be indicated when presenting the results.

5.1.3.2 Channel-specific parameters

Results for equal power distribution on REs are mandatory.

Unequal power distribution between channels or between RS and channels can be applied; the power configuration is left to the companies to decide and should be indicated when presenting the results.

The following acronyms are used in this section:

- Pmiss: Probability of missed detection;
- Pfa: Probability of false alarm;
- TBI: "To Be Indicated", which means the related parameter is not specified but each company has to indicate its value when presenting the results;
- TBS: Transport Block Size;
- rBLER: residual BLER after retransmission;
- iBLER: initial BLER.

Table 5-3: LTE UL channels parameters for coverage issues identification

Channel / Assumptions	RACH Format 2	PUCCH format 1	PUCCH format 1a	PUCCH format 2	Message 3 TBS 56	Message 3 TBS 144
Performance target	1% Pmiss (baseline) 10% Pmiss (optional) 0.1% Pfa	1% Pmiss 1% Pfa	1% Pmiss 1% Pfa	1% BLER	10% rBLER	10% rBLER
Max Number of HARQ retransmissions	N/A	N/A	N/A	N/A	TBI	TBI
PUSCH hopping	N/A	N/A	N/A	N/A	ON	ON
TTI bundling	N/A	N/A	N/A	N/A	N/A	N/A
RLC segmentation	N/A	N/A	N/A	N/A	N/A	N/A
Number of UL RBs	N/A	1	1	1	TBI	TBI
MCS number	N/A	N/A	N/A	N/A	TBI	TBI

Table 5-4: LTE UL channels parameters for coverage issues identification (continued)

Channel / Assumptions	VoIP AMR 12.2 kbps	Medium data rate PUSCH 384 kbps	Minimum data rate PUSCH (2nd priority, bit rate is FFS)
Performance target	2% rBLER	10% iBLER	10% iBLER
Max Number of HARQ retransmissions	TBI	TBI	TBI
PUSCH hopping	ON	TBI	TBI
TTI bundling	ON	TBI	TBI
RLC segmentation	ON or OFF	TBI	TBI
Number of UL RBs	TBI	TBI	TBI
MCS number	TBI	TBI	TBI

Table 5-5: LTE DL channels parameters for coverage issues identification

Channel / Assumptions	PDCCH Format 1A Format 2C	PBCH	PHICH	PCFICH	P-SCH	S-SCH	VoIP 12kbps	Medium data rate PDSCH 1 Mbps
Performance target	1% BLER	1% BLER	0.1% BLER	1% BLER	10% Pmiss	10% Pmiss	10% iBLER	10% iBLER
Max Number of HARQ retransmissions	N/A	N/A	N/A	N/A	N/A	N/A	TBI	TBI
Number of DL RBs	N/A	N/A	N/A	N/A	N/A	N/A	TBI	TBI
MCS number	N/A	N/A	N/A	N/A	N/A	N/A	TBI	TBI
Other assumptions	Aggregation level: 4 CCEs and 8 CCEs							

Table 5-6: UMTS Rel-99 UL channels parameters for coverage issues identification

Channel / Assumptions	RACH	Voice AMR 12.2kbps

Performance target	1% Pmiss (baseline) 10% Pmiss (optional) 0.1% Pfa	1% BLER

5.2 Evaluation Results

Evaluation results were provided by 12 companies [4]. .

Based on the assumptions in Section 5.1.3, following assumptions were further adopted by the companies:

- EPA channel model;
- Practical channel estimation;
- UE antenna configuration: 1Tx2Rx.

Most companies' results were based on 2Tx2Rx eNB configuration, with following assumptions:

- FDD, bandwidth=10M Hz;
- Payload of PUCCH format 2: 4 bits.

One company's results were based on 8Tx8Rx eNB configuration, with following assumptions:

- TDD, bandwidth=20M Hz;
- PHICH 8 A/Ns, SF = 4, 3 repetition;
- Payload of PUCCH format 2: 10bit;
- 3 out 5 in each 5ms is downlink subframe, 2 out 5 in each 5ms is uplink subframe.

Table 5-7: Evaluation results of LTE UL channels (2Tx2Rx eNB configuration)

Channels	Performance target	MCL(dB)								
		Source 1	Source 2	Source 3	Source 4	Source 5	Source 6	Source 7	Source 8	Source 9
RACH Format 2	1%Pmiss 0.1%Pfa	142.24	141.79	140.27	143.99	140.29	141.60	141.67	-	142.27
	10%Pmiss 0.1%Pfa	-	-	-	-	-	147.10	145.67	-	-
PUCCH format 1	1% Pmiss, 1%Pfa	146.25	147.95	144.95	146.05	145.85	147.50	145.25	147.50	147.25
	1%Pmiss 0.1%Pfa	-	-	-	-	-	146.30	-	-	-
PUCCH format 1a	1% Pmiss, 1%Pfa	146.25	147.45	147.15	145.55	146.85	152.65	145.25	147.00	147.05
PUCCH format 2	1%BLER	144.95	146.15	146.35	145.65	146.55	146.45	144.85	146.50	146.45
Message 3 TBS 56	10%rBLER	147.04	145.05	-	146.95	147.24	148.50	-	147.00	145.28
	10%iBLER	-	-	139.24	-	-	-	138.25	-	-
	1%rBLER	-	-	-	-	-	145.90	140.65	-	-
Message 3 TBS 144	10%rBLER	142.98	141.59	-	142.68	144.08	146.10	-	144.00	142.93
	10%iBLER	-	-	135.91	-	-	-	135.44	-	-

	1%rBLER	-	-	-	-	-	143.50	138.94	-	-
VoIP AMR 12.2 kbps	2%rBLER	141.08	139.03	143.53	143.45	138.78	143.54	142.35	-	141.68
Medium data rate PUSCH 384kbps	10%iBLER	136.23	131.68	130.67	132.50	132.73	131.53	129.96	133.40	132.96
Minimum data rate PUSCH (2nd priority, bit rate is FFS)	10%iBLER	-	-	-	-	-	-	140.65	-	-

Table 5-8: Evaluation results statistics of LTE UL channels (2Tx2Rx eNB configuration)

Channels	Performance target	Number of sources	MCL(dB)			
			Average	Maximum	Minimum	STD
RACH Format 2	1%Pmiss 0.1%Pfa	8	141.77	143.99	140.27	1.11
	10%Pmiss 0.1%Pf	2	146.39	147.10	145.67	0.72
PUCCH format 1	1%Pmiss, 1%Pfa	9	146.51	147.95	144.95	1.02
	1%Pmiss 0.1%Pfa	1	146.30	146.30	146.30	N/A
PUCCH format 1a	1%Pmiss, 1%Pfa	9	147.24	152.65	145.25	2.04
PUCCH format 2	1%BLER	9	145.99	146.55	144.85	0.64
Message 3 TBS 56	10%rBLER	7	146.72	148.50	145.05	1.10
	10%iBLER	2	138.75	139.24	138.25	0.50
	1%rBLER	2	143.28	145.90	140.65	2.63
Message 3 TBS 144	10%rBLER	7	143.48	146.10	141.59	1.32
	10%iBLER	2	135.68	135.91	135.44	0.24
	1%rBLER	2	141.22	143.50	138.94	2.28
VoIP AMR 12.2 kbps	2%rBLER	8	141.68	143.54	138.78	1.81
Medium data rate PUSCH 384kbps	10%iBLER	9	132.41	136.23	129.96	1.71
Minimum data rate PUSCH 14.4kbps	10%iBLER	1	140.65	140.65	140.65	N/A

Table 5-9: Evaluation results of LTE DL channels (2Tx2Rx eNB configuration)

Channels	Performance target	MCL(dB)					
		Source 1	Source 3	Source 4	Source 5	Source 7	Source 9
PDCCH format 1a	1%BLER(8CCE)	146.26	143.76	145.70	147.86	146.00	146.76
	1%BLER(4CCE)	-	-	-	-	143.30	-
PDCCH format 2c	1%BLER(8CCE)	144.56	-	144.60	146.86	144.50	145.66
	1%BLER(4CCE)	-	-	-	-	141.70	-
PBCH	1%BLER	149.96	147.76	149.60	148.56	148.00	149.16
PHICH	0.1%BLER	147.36	143.36	146.00	145.56	144.00	145.96

PCFICH	1%BLER	147.26	144.36	146.60	146.46	142.5	147.46
PSS	10%Pmiss	147.66	146.46	150.21	-	147.00	153.96
SSS	10%Pmiss	147.66	146.46	-	-	147.00	153.66
VoIP 12kbps	10%iBLER	143.96	140.46	147.66	139.06	140.50	145.46
Medium data rate PDSCH 1Mbps	10%iBLER	143.77	143.56	147.73	139.36	145.00	146.76

Table 5-10: Evaluation results statistics of LTE DL channels (2Tx2Rx eNB configuration)

Channels	Performance target	Number of sources	MCL(dB)			
			Average	Maximum	Minimum	STD
PDCCH format 1a	1%BLER(8CCE)	6	146.06	147.86	143.76	1.24
	1%BLER(4CCE)	1	143.30	143.30	143.30	N/A
PDCCH format 2c	1%BLER(8CCE)	5	145.24	146.86	144.50	0.92
	1%BLER(4CCE)	1	141.70	141.70	141.70	N/A
PBCH	1%BLER	6	148.84	149.96	147.76	0.80
PHICH	0.1%BLER	6	145.37	147.36	143.36	1.33
PCFICH	1%BLER	6	145.77	147.46	142.50	1.78
PSS	10%Pmiss	5	149.06	153.96	146.46	2.77
SSS	10%Pmiss	4	148.70	153.66	146.46	2.90
VoIP 12kbps	10%iBLER	6	142.85	147.66	139.06	3.08
Medium data rate PDSCH 1Mbps	10%iBLER	6	144.36	147.73	139.36	2.69

Table 5-11: Evaluation results of LTE UL channels (8Tx8Rx eNB configuration)

Channels	Performance target	MCL(dB)
		Source 10
RACH Format 2	1%Pmiss 0.1%Pfa	146.67
PUCCH format 1a	1%Pmiss, 1%Pfa	149.45
PUCCH format 2	1%BLER	146.35
Message 3 TBS 56	10%rBLER	152.45
Message 3 TBS 144	10%rBLER	148.64
VoIP AMR 12.2 kbps	2%rBLER	143.93
Medium data rate PUSCH 384kbps	10%iBLER	134.99

Table 5-12: Evaluation results of LTE DL channels (8Tx8Rx eNB configuration)

Channels	Performance target	MCL(dB)
		Source 10
PDCCH format 1a	1%BLER(8CCE)	143.95

PHICH	0.1%BLER	144.75
PCFICH	1%BLER	144.95
Medium data rate PDSCH 1Mbps	10%iBLER	138.55

Summary on coverage issues identification:

1. LTE with 2Tx&2Rx at base station and 1Tx&2Rx at UE
   - UL is the limiting factor in terms of coverage
     - PUSCH (medium data rate) is poorer than other channels, with significant gap observed.
     - With strict performance targets (e.g. 1% Pmiss, 1% rBLER or 10% iBLER), PRACH and/or Msg 3 are the potential limiting factor.
       - It's realized that relaxed performance targets at cell edge would be beneficial to enhance random access channels' coverage.
     - PUSCH (VoIP) is the potential limiting factor, especially with relaxed performance targets for PRACH/Msg3.
     - PUCCH channels are well balanced in general.
       - Imbalance between PUCCH formats may exist, with PUCCH format 1a repetition.
   - The coverage of DL is better than UL in general

2. LTE with 8Tx&8Rx at base station and 1Tx&2Rx at UE
   - PUSCH (medium data rate) is poorer than other channels.
   - PUSCH (VoIP) and PDCCH (/PCFICH/PHICH) are the potential limiting factors.

5.3 Conclusion on Further Investigations

- Further investigate coverage enhancements for medium data rate and VoIP in UL with first priority, and for Msg3 with second priority.
- Further investigate coverage enhancements for DL control channel(s). And this part is proposed to be processed in "Enhanced downlink control channel(s) for LTE" WI.
- Further enhancements for other channels are FFS.

6 Solutions for Coverage Enhancements

TTI bundling is specified as follows in Release 8/9/10 to improve UL coverage:

- A single transport block is channel coded and transmitted in a set of 4 consecutive TTIs.
- The bundled TTIs are treated as a single UL resource assignment where a single UL grant and a single PHICH ACK/NACK are required.
- TTI bundling is activated through RRC.
- HARQ RTT and HARQ process of TTI bundling are specified.

In the Release 8/9/10 specifications, the TTI bundling mechanism is restricted to bundles of 4 TTIs, QPSK modulation and to allocations up to 3 PRBs. For VoIP, these constraints leave some room to further improve the amount of energy transmitted per information bit, and thus the coverage. Higher data rate services can potentially benefit from reduced overhead and larger coding gain resulting from larger transport block sizes associated with TTI bundling. These constraints impose restrictions on the support of large packet sizes, thus limiting the benefit for data services.

It is agreed to further investigate TTI bundling enhancements for both medium data rate and VoIP in UL. The following potential enhancements have been identified:

6.1 TTI bundling enhancements for medium data rate PUSCH

6.1.1 Description

The TTI bundling enhancements should target for exploiting the coding gain, improving the diversity, reducing the overhead and so on. Candidate solutions are as follows:

- Allowing more than 3 PRBs allocated per subframe

Larger transport block size can be supported in TTI bundling case when more PRBs are allocated. This brings benefits including more channel coding gain, more flexibility of resource allocations, and so on.

Other solutions for further study are as follows:

- Enhanced method to get larger TBS from the TBS table.
- Enhanced hopping, taking into account of channel estimation accuracy.
- Support for bundling with higher order modulation.

6.1.2 Coverage gain

For performance evaluation, Rel-8 PUSCH 384 kbps without TTI bundling or with TTI bundling (limited to 3PRB) is the reference. Here, the simulation assumptions listed in Table 5-2 and Table 5-4. Note that PUSCH frequency hopping is turned on in most companies' simulations in this configuration. The performance metrics can include:

- The required SNR values to achieve 10% iBLER with fixed MCS configuration
- The required SNR values to achieve effective rate of 384 kbps with the setting of multiple HARQ transmissions and adaptive MCS selection targeting for 10% iBLER

In Table 6-1, coverage gains in terms of required SNRs are listed.

Table 6-1: Coverage gains in terms of required SNRs

~384 kbps PUSCH	Fixed MCS, 10% iBLER						Adaptive MCS, effective data rate	
	Source 1 [5]	Source 2 [6]	Source 3 [8]	Source 4 [7]	Source 5 [17]	Source 6 [18]	Source 7 [10]	Source 8 [9]
Gain (dB)	~1.7*	~0.5	~1.3	3.7**	0.7	0.5	0.8	1.1***

Note: Differences to the results are observed due to implementation differences and large difference in simulation assumptions.

* New frequency pattern is assumed for TTI enhancements.

** Include link adaptation optimization and frequency diversity gains.

*** The $N_{PRB} * N_{TTI}$ is used for TBS table lookup.

It can be observed from the results in Table 6-1 that a coverage gain in the order of 1 dB can be expected..

6.1.3 Expected impact on the network

Different handling between legacy and supporting Ues needs to be implemented in the eNodeB.

The following additional impacts on network could be expected:

- Increase the flexibility of resource allocations
- Reduce the control overhead

6.1.4 Specification impact

- Introducing a new TTI bundling mode or new TTI bundling behaviour
- The specification of this new TTI bundling mode or behaviour may include at least the following item:
    - allocating more than 3 PRBs per subframe

6.2 TTI bundling enhancements for UL VoIP

6.2.1 Description

Given the fixed arrival rate of voice packets, TTI bundling enhancements for VoIP can improve the time resource utilization so that more energy can be accumulated for a voice packet within the delay budget. Candidate solutions are as follows:

- Reduced round trip time

  Reduced round trip time can bring benefits for more energy accumulation for VoIP within given delay budget.

- Extended bundle size

  Another candidate to accumulate more energy for VoIP within given delay budget is to extend the bundle size. The bundle size could be fixed or flexible.

- Enhanced method to increase the time diversity

  Bundled TTIs can be interleaved in time, so that PUSCH transmission spans over longer time.

- Addition of spreading

  TTI bundling with retransmissions involves repeating the coded bits. An alternative way of achieving repetition is to use spreading, which has the additional benefit of increasing the robustness with respect to interference. A similar structure as PUCCH format 3 could be used in order to add the spreading dimension.

It is for further study to extend TTI bundling to more TDD DL/UL configurations.

TTI bundling enhancements may take into account of improvement of diversity and channel estimation accuracy.

6.2.2 Coverage gain

Rel-8 VoIP TTI bundling is considered as the baseline, with the frequency hopping turned on. The performance is measured by the required Es/Nt for 2% residual BLER within around 50 ms delay budget. Results from all available sources indicate that around 1 dB gain can be achieved when overall 20 ms transmission time is utilized.

Table 6-2: Coverage gains, fixed 2% residual BLER, within around 50 ms delay budget

	Gain (dB)	Rel-8 reference	Enhanced scheme	Key simulation assumptions
Source 1 [11]	1.0	16 ms RTT, Max HARQ=4, Rel-8 inter-subframe frequency hopping	4-TTI bundling, 12 ms RTT, Max HARQ=5, new frequency hopping pattern	Realistic channel estimation, 3 PRBs
Source 2 [6]	~1.0	16 ms RTT, Max HARQ=4	4-TTI bundling, 16 ms RTT, Max HARQ=5	Realistic channel estimation, 1 PRB, Rel-8 inter-subframe frequency hopping
Source 3 [7]	1.0	16 ms RTT, Max HARQ=4	4-TTI bundling, 8 ms RTT, Max HARQ=6	Rel-8 inter-subframe frequency hopping

Source 4 [12]	1.0	16 ms RTT, Max HARQ=4	4-TTI bundling, 12 ms RTT, Max HARQ=5	Ideal channel estimation, Rel-8 inter-subframe frequency hopping
Source 5 [13]	1.5	16 ms RTT, Max HARQ=4	4-TTI bundling, 12 ms RTT, Max HARQ=5	1 PRB, Rel-8 inter-subframe frequency hopping
Source 6 [10]	0.9	16 ms RTT, Max HARQ=4	10-TTI bundling, Max HARQ=2	Realistic channel estimation, Rel-8 inter-subframe frequency hopping
Source 7 [14]	~1.0	16 ms RTT, Max HARQ=4	4-TTI bundling, Max HARQ=5	Realistic channel estimation, Rel-8 inter-subframe frequency hopping
Source 8 [15]	1.0	16 ms RTT, Max HARQ=4	4-TTI bundling, 12 ms RTT, Max HARQ=5. Or 5-TTI bundling, 15 ms RTT, Max HARQ=4.	Ideal channel estimation, No frequency hopping
Source 9 [16]	0.5/0.6	16 ms RTT, Max HARQ=4	Flexible bundling size, Max 20 TTIs for a VoIP packet	Realistic channel estimation, Frequency hopping/ dymamic scheduling
Source 10 [17]	0.8	4-TTI bundling, with 4 processes	8-TTI bundling, with 2 processes	No re-transmission
Source 11 [18]	2	No bundling, with segmentation	4-TTI bundling	Frequency hopping

It is observed that the coverage gain can be achieved by dynamic scheduling [16] with higher PDCCH overhead compared to semi-static scheduling. Applicability of dynamic scheduling in all mobility scenarios may not be guaranteed, due to potential limits in measurements accuracy.

6.2.3 Expected impact on the network

The following impacts on network could be expected:

- Reduced round trip time may have impact on scheduler implementations and/or signalling mechanism needing to handle multiple different RTTs for different users. It may result in less efficient resource utilization or higher control overhead. The resources used with less efficiency, if any, would be restricted to the PRBs allocated to the VoIP users close to the coverage limit, which are typically assigned a low number of PRBs (e.g. 1 or 3).
- Extended bundle size may reduce the flexibility in resource allocation.
- Addition of spreading may require new receiver algorithms, channel and interference estimation. It may also require additional network planning and coordination.

6.2.4 Specification impact

- Introducing a new TTI bundling mode or new TTI bundling behaviour.
- The specification of the new TTI bundling mode or behaviour may include one or more of the following items
    - HARQ timing
    - number of TTIs bundled, including fixed or flexible bundle size
    - time interleaving of bundled TTIs

- PUCCH format 3 structure type uplink transmission mode

7 Conclusions

According to the discussions and performance evaluation results captured in the previous sections, the following conclusions can be drawn:

- The coverage benefit is observed from TTI bundling enhancements for medium data rate PUSCH. Potential solutions may impact the specifications at least from one of the following aspects
  - allocating more than 3 PRBs per subframe
- The coverage benefit is observed from TTI bundling enhancements for UL VoIP. Potential solutions may impact the specifications at least from one of the following aspects
  - HARQ timing
  - number of TTIs bundled, including fixed or flexible bundle size
  - time interleaving of bundled TTIs
  - PUCCH format 3 structure type uplink transmission mode
- It is recommended to specify TTI bundling enhancements for coverage enhancements for medium data rate PUSCH and UL VoIP.
  - It is noted that the schemes studied for UL VoIP coverage enhancement offer similar improvement, at least in noise-limited environments. In selecting between enhancements with similar performance, priority should be given to enhancements with lower impact on the specifications, system operation and implementation complexity.

Annex A: Change history

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
2012-02	RAN1#68				— Proposes the skeleton of the TR, based on RP-111359. — Captures the agreements from the email discussion [66bis-12] and [67-10].		0.1.0
2012-02					Inclusion of the descriptions on potential solutions, based on the agreements in R1-120900.	0.1.0	0.2.0
2012-02					Approved by the email discussion [68-16]	0.2.0	1.0.0
2012-05	RAN1#69				Inclusion of the agreements in RAN1#69.	1.0.0	2.0.0
2012-06	RAN_56	RP-120693			Approved at RAN#56 as version 11.0.0	2.0.0	11.0.0