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Technical Report

3rd Generation Partnership Project;
Technical Specification Group GERAN;
GERAN Improvements for Machine-type Communications;

(Release 11)

GLOBAL SYSTEM FOR MOBILE COMMUNICATIONS

A GLOBAL INITIATIVE

Style Definition

Keywords

<keyword[, keyword]>

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Contents

Foreword

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

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

Introduction

The present document captures the results of the feasibility study for GERAN improvements for Machine-type Communications.

1 Scope

The present document contains the results from the study of improvements for Machine-type Communications in GERAN.

The following items shall be covered in the study:

- GERAN enhancements for Smart metering
- Enhancements which enable or improve efficient use of RAN resources and/or which lower complexity when a large number of MTC devices are served.
- GERAN enhancements for overload and congestion control on the radio, A and Gb interface
- GERAN enhancements regarding identifiers used for MTC devices in the radio access network

[Editor's note: The scope may be expanded as the study progresses.]

2 References

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

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

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

[2] 3GPP TS 22.368: "Service requirements for machine-type communications; Stage 1".

[3] SP-100224 Liaison Statement: Prioritization of NIMTC functions in Rel-10

[4] 3GPP TS 44.018 Mobile radio interface layer 3 protocol; Radio Resource Control (RRC) protocol

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

MTC Device: A MTC Device is a UE equipped for Machine Type Communication, which communicates through a PLMN with MTC Server(s) and/or other MTC Device(s).

NOTE: A MTC Device might also communicate locally (wirelessly, possibly through a PAN, or hardwired) with other entities which provide the MTC Device "raw data" for processing and communication to the MTC Server(s) and/or other MTC Device(s). Local communication between MTC Device(s) and other entities is out of scope of this technical specification.

MTC Feature: MTC Features are network functions to optimise the network for use by M2M applications.

example: text used to clarify abstract rules by applying them literally.

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] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].)

CCCH	Common Control Channel
GERANIMTC	GERAN Improvements for Machine Type Communications
IP	Internet Protocol
KPI	Key Performance Indicator
MS	Mobile Station
MTC	Machine Type Communications
PDCH	Packet Data Channel

4 Areas for study to effectively support MTC in GERAN

4.1 General

Sub-section 4 contains the outcome of the study of GERAN enhancements driven by the prioritized general MTC functions as defined in [3] that are considered applicable to GERAN specifications.

4.2 Overload control

4.2.1 General

Overload Control refers to use cases Radio Network Congestion, Signalling Network and Core Network Congestion as described in [2] Annex A.

4.2.2 Description and Analysis

4.2.2.1 CCCH Overload Control

4.2.2.1.1 Description and Analysis

The large amount of access attempts that can be generated from mobile stations used for MTC is believed to increase the load and cause congestion on the common control channel (CCCH) and therefore may negatively impact legacy services.

The legacy pre-release 10 RR connection establishment procedure is not sufficient for the network to avoid CCCH congestion that can be caused by mobile stations used for MTC. However the implicit reject procedure specified in release 10 in 3GPP TS 44.018 can effectively protect the legacy services from CCCH congestion that can be caused by mobile stations configured with low access priority.

4.2.2.1.2 Result

By using the implicit reject procedure, the network can effectively protect the CCCH from being overloaded by mobile stations configured with low access priority.

The objective of CCCH overload control in MTC study has been met with the implicit reject procedure with respect to preventing overload of CCCH hence minimising impact to legacy services from devices configured for low access priority.

4.2.3 Result

[Editor's note: This section identifies the impacts on GERAN specifications resulting from the functionality.]

…..

4.3 Identifiers

4.3.1 General

The functionality Identifiers refers to sub-section 7.1.4 in [2].

4.3.2 Description and Analysis

[Editor's note: This section provides the description and the analysis of the functionality.]

4.3.3 Result

[Editor's note: This section identifies the impacts on GERAN specifications resulting from the functionality.]

….

5 MTC Use Cases

5.1 General

Sub-section 5 contains the outcome of the study of GERAN enhancements for prioritized general MTC functions specific for MTC uses cases seen as relevant to support within a GERAN network.

5.2 Smart Metering

5.2.1 Overload control

5.2.1.1 Enhancement: …

[Editor's note: This section provides the description and the analysis of functional enhancements.

5.2.1.2 Result

[Editor's note: This section identifies the impacts on GERAN specifications resulting from functional enhancements.]

5.2.2 Identifiers

5.2.2.1 Enhancement: …

[Editor's note: This section provides the description and the analysis of functional enhancements.

5.2.2.2 Result

[Editor's note: This section identifies the impacts on GERAN specifications resulting from functional enhancements.]

5.3 *<Use Case2>*

6 Common Assumptions

6.1 Traffic model

6.1.1 General

The traffic model is assumed to be mobile originated, meaning that the MTC server will not poll/request reports from the MTC devices. Hence, the MTC devices will require access to the network rather autonomously and thus the network need not page the MTC devices.

6.1.2 CCCH Signalling

In order to capture different network access behaviors the investigated scenarios are divided in both synchronized and non-synchronized access.

Three different traffic models are used as listed in Table 1.

Table 1. Traffic models.

Traffic model	Description
T1	MTC devices accessing the network in an uncoordinated/non-synchronized manner
T2	MTC devices accessing the network in a coordinated/synchronized manner with a certain distribution
T3	Legacy devices accessing the network in an uncoordinated/non-synchronized manner

Table 2. CCCH Traffic Scenarios

Scenario	T1	T2	T3
Number of devices	λ / (Reporting interval)[1]	X	λ / (Reporting interval) [1]
Arrival process	Poisson Arrival intensity: λ [arrivals/second]	Time limited deterministic event distribution. See 2.1.1. The time-spread of the distribution is controlled by parameter T [s], which shall include T=1.	Poisson Arrival intensity: λ [arrivals/second] Case 1: λ = 5 for CS traffic Case 2: λ = 5 for CS traffic and λ = 15 for PS traffic
Reporting interval	• 5 seconds • 15 minutes • 1 hour • 1 day	NOTE: With this traffic model reporting interval is not defined since the number of devices are fixed and the access need to be finished by all devices before the following access can take place.	N/A
Report Sizes	• 10 byte • 200 byte • 1000 byte	• 10 byte • 200 byte • 1000 byte	N/A

Scenario T1 can be considered to be quite realistic, since for a large amount of users the overall arrival process can be modelled as a Poisson arrival process regardless of the individual arrival process.

Scenario T2 models the behavior when e.g. multitude of ill-configured power meters are set to deliver their measurements at the same time or when the meters starts reporting after e.g. a power outage. The MTC devices are here assumed to be synchronized within an interval of T seconds.

Scenario T3 models the behavior of CS and PS legacy devices where the overall arrival processes (separate for CS and PS) can each be modelled as a Poisson arrival process as the devices are assumed to be initiated independently of each other. Scenario T3 shall be regarded as the reference case when evaluating impacts on legacy mobiles and the ASR for CS services simulated in Scenario T3 shall be over 98%.

The overall objective of the T3 scenario is to be used in conjunction with either the T1 or T2 scenario, respectively, to evaluate the impact of the MTC traffic on the legacy traffic.

In the simulations, the network shall not use pre-emptive retransmissions of messages on the CCCH/D.

6.1.2.1 Time limited deterministic event distribution

Following considerations are made:

Assuming that all events take place between $t=0$ and $t=T$, the intensity is described by the distribution p(t) and the total number of devices in the cell is X, then the number of arrivals in the i:th TDMA frame is given by:

[1] NOTE: This assumption is roughly true as long as the data session duration is shorter than the reporting interval.

$$\#RACH(i)=\left\lfloor X\int_0^{t_{i+1}} p(t)dt\right\rfloor-\left\lfloor X\int_0^{t_i} p(t)dt\right\rfloor, where \qquad t_i = i\cdot(TDMA frame duration)$$

Equation 1 – Number of arrivals in a given TDMA-frame

Any distribution should preserve the total number of access attempts when time duration T is changed, and should be limited in time:

$$\int_0^T p(t)dt = 1.$$

The distribution used in this feasibility study is the so called Beta distribution, please see section 6.2.2.1.1.

6.1.2.1.1 Beta distribution

The benefit of this model is:

- This deterministic traffic model simplifies simulation (by virtue of being deterministic). It may be considered to approximate the traffic load generated by multiple devices accessing the network quasi-simultaneously (the selection of a time window of 1 second is arbitrary).

$p(t)=\dfrac{t^{\alpha-1}(T-t)^{\beta-1}}{T^{\alpha+\beta-1}Beta(\alpha,\beta)}\alpha>0,\beta>0$, where $Beta(\alpha,\beta)$ is the Beta function.

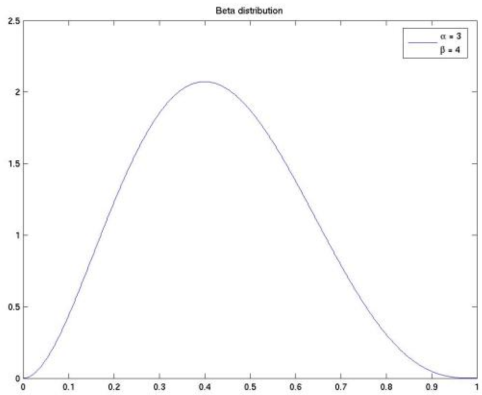

Figure 1 - The Beta distribution with α=3, β=4 when T=1

The values of α=3 and β=4 for traffic model T2 are used, which gives the PDF that is depicted in Figure 1 above for the case when T=1.

6.1.3 Traffic model on PDCH

It is assumed that traces from CCCH Signalling simulations as defined in section 6.2.2 are used to model the traffic for the PDCH simulations.

6.2 Methodology

6.2.1 Simulator methodology

A single cell evaluation of possible congestion of the CCCH and PDCH is used.

Either a single cell simulator (sometimes also referred to as a protocol level simulator) or system level type simulator can be used where the basic difference is in that the system level simulator models dynamic interference from neighbouring cells while the single cell simulator uses network traces (see 6.3.1.1) to generate external interference.

Irrespective of simulator level used network traces, as described in 6.3.1.1, shall be presented for easier comparison of results from different companies.

6.2.1.1 Network trace

In order to get a simplified distribution of the interfering signal that network level simulations are run to collect the signal distributions of the interferer.

Further on, the derived interference distribution is presented in tabulated format to allow for easier comparison and verification of contributions from different companies.

Note that the collection of signal interferers might be different depending on the traffic scenario investigated, i.e. CCCH or PDCH congestion. E.g. the CCCH distributions will be based on I_{ext}, as defined in section 6.3.2.5.1, while the distributions used for the PDCH evaluation is left vendor specific, see section 6.3.2.5.2 .

An example of a tabulated distribution of external interference for the RACH simulations is given in Figure 2.

I_{ext}	
Signal level [dBm]	CDF value
-110	0
-109	0.02
-108	0.03
-107	0.05
.	.
.	.
.	.
.	.
-29	0.98
-30	1

Figure 2. Example of RACH interferer distribution.

6.2.1.2 Network load

The resource allocation from the background traffic in neighbouring cells is assumed to be fully allocated (constant transmission), transmitted at full power (no power control) using 8PSK modulation (for assumptions on power back-off see Table 3).

6.2.1.3 Cell under investigation

For the cell under investigation all traffic is assumed to be MTC devices while the background noise is assumed to be best effort PS traffic modelled as described in section 6.3.1.2. This should be seen as a worst case scenario in terms of network access attempts.

6.2.1.4 Service coverage

Full service coverage of stationary MTC devices should be assumed, i.e. no service outage is accepted. This is ensured by allowing only minimum signal levels of -104 dBm – 3 for each MTC device, where an additional gain of 3 dB is assumed for a dual antenna MRC type BTS architecture. This would guarantee GMSK coverage. The minimum signal level shall include fast fading, since TU0 is used (see 6.3.2.2).

6.2.2 Simulation assumptions

6.2.2.1 General

This section defines the parameters required for the simulations which may be required to conduct the study. The parameters are referenced where appropriate.

Table 3. Network level simulator parameters

Parameter		Value	Unit	Comment
Sectors per site		3		
Sector antenna pattern		65º deg H-plane, max TX gain 15	dBi	18 dBi antennas in 900-band are large and not considered to be common in urban areas.
Path loss model		Per 30.03, Hb = 5 m,	dB	In urban areas, 5 m over average roof height is considered more typical than the default value of 15 m in 30.03.
Minimum coupling loss		64	dB	1800: TR 25.942 2 GHz. 900: assumed 6 dB lower
Building penetration loss		15 / 20	dB	Indoor 1 / Indoor 2
Indoor 1/Outdoor devices		90 / 10	%	Scenario 1
Indoor 1/Indoor 2 devices		50 / 50	%	Scenario 2
Interference model		Neighbouring cells BCCH		The neighbouring cells according to the BCCH frequency reuse pattern are modelled as if they have full traffic.
Log-normal fading	Standard deviation	8	dB	
	Correlation distance	110	m	NOTE: For the cell under investigation it is not essential to model stationary devices (TU0), thus a correlation distance of 0 m can be used. Fewer cell realizations needed if this value is zero.
Channel propagation		See table 6		
Output power - MS		33	dBm	Excluding backoff

- BTS	43		
Backoff - MS	6	dB	
- BTS	4	dB	8PSK modulation assumed.
Noise figure - MS	10	dB	
- BTS	8	dB	
Inter-site log-normal correlation coefficient	0		Low correlation in urban scenarios.

Table 4. Network scenario

Parameter	Value	Unit	Comment
Frequency band	900	MHz	
Cell radius	500	m	
Bandwidth	2.4	MHz	
Number of channels	12		
BCCH frequency reuse	4/12		
BCCH or TCH under interest	BCCH		

Table 5. Protocol level parameters

Parameter	Value	Comment
CCCH assumptions • Tx-integer • S • Max. retrans (M) • T3142 • T3146	 20 109 4 5 sec. (Tx+2S)/217=1.1 sec.	These default values shall be included among those evalutated. See 3GPP TS 44.018 for implementation details
BCCH configuration	Non-combined	
# PDCHs	4	Number of PDCHS availabale data traffic
# AGCHs per 51-multiframe	6	
PDCH Resource Assignment	1 TS UL + 1 TS DL (BTTI)	
Link adaptation	Enabled	
Service type	1. EGPRS 2. GPRS	
RLC mode of operation	Acknowledged Mode (AM)	

Table 6. Link specific settings.

Parameter	Value	Comment
Channel profile [MTC]	TU3 TU0	For PS users to derive network level trace on UL 1. For MTC devices in protocol level

		simulations 2. For PS users to derive network level trace on DL
Receiver type UL	MRC	
Incremental redundancy	Enabled (only for EGPRS)	See Table 5

6.2.2.2 Path loss

It is assumed that the gain (path loss + shadow fading + antenna gain) from a given MS to its serving BTS is the same in UL and DL.

6.2.2.3 Channel propagation

It is assumed that the external interferers experience a TU3-channel while the MTC devices are assumed to be stationary and subject to TU0-channel propagation.

6.2.2.4 External interference

It is assumed that the external interference levels are uncorrelated between the DL and UL, i.e. that uncorrelated samples are used from the respective distributions.

6.2.2.5 Application protocol

It is assumed that the MTC application is using UDP as a transport protocol with acknowledgments on the application layer from the MTC server to the MTC client will be transmitted, i.e. there will both be PUANs and data blocks (containing application Acks) transmitted in the DL for the PDCH evaluation. Details are left FFS.

During a simulation session the application performs a single access attempt, i.e. there shall be no re-attempts triggered by the application.

6.2.2.5.1 IP version

The IP version to use for the evaluation is left FFS.

6.2.2.6 Link model

6.2.2.6.1 CCCH

A simplistic link-to-system interface is assumed.

It is assumed that only a total co-channel interference level needs to be assumed for each burst. Adjacent channel suppression is assumed to be 18 dB. To capture the correct combined channel propagation behavior of the total interfering signal, impacts on fast fading is proposed to be included in the signal distribution of the interferer.

6.2.2.6.1.1 RACH (CCCH/U)

For possible reception of an access burst, $C_{RACH}/(I_{RACH} + I_{TOT})$ needs to be greater than 9 – 3 = 6 dB. RACH reference interference ratio is specified at 9 dB (Channel propagation TU3, 3GPP TS45.005) and an additional gain of 3 dB is assumed for a dual antenna MRC type BTS architecture.

On top of this an error rate of 15% is added (RACH reference interference performance, TU3, 45.005).

This should be seen as a worst case scenario since no errors could be expected above a certain $C_{RACH}/(I_{RACH} + I_{TOT})$ threshold.

NOTE: The figures above are being investigated. It could be considered instead to leave this unspecified and document it when results are displayed.

6.2.2.6.1.2 AGCH (CCCH/D)

For possible reception of an access grant, C_{AGCH}/I_{TOT} needs to be greater than 9 dB. AGCH reference interference ratio is specified at 9 dB (Channel propagation TU3, 3GPP TS45.005).

On top of this an error rate of 22% is added (AGCH reference interference performance, TU3, 45.005).

NOTE: The figures above are being investigated. It could be considered instead to leave this unspecified and document it instead when results are displayed.

6.2.2.6.2 PDCH

Vendor specific L2S mapping methodology is to be used that can be verified against a set of pre-defined interferer scenarios.

Common assumptions for the UL receiver include:

- Dual antenna base station
- MRC receiver algorithm.

Common assumptions for the DL receiver include:

- Single antenna mobile station

6.2.2.7 Number of CCCHs

The CCCH performance is evaluated using a single CCCH.

6.3 Output

6.3.1 General

All results should be presented as per indicated below. It should be noted that this list is not exhaustive and that outputs not currently listed cannot be precluded that could affect the conclusions of this work.

Upon evaluation of different proposals, the KPIs of services with a higher priority shall be seen to take precedence over the KPIs of services with lower priority. The Access success rate for legacy CS services shall be considered more crucial than the Access success rate of a MTC device configured for low-access-priority.

6.3.2 Overall MTC simulation and evaluation output

- MTC success rate = Number of successfully received reports (i.e. all application level payload associated with this report) sent from the device to the network divided by the total number of arrivals.
- MTC delay = The time it takes for a MTC device to successfully transfer its application level payload, as from when it makes its first application initiated access [50/95/99 percentile].
- MTC coverage outage = Percentage of MTC devices that are initially placed out of coverage.

6.3.3 CCCH signalling output

- Access success rate = Number of successful Immediate Assignment procedures, see sub-clause 3.3.1.1 in [4] divided by total number of Immediate Assignment procedures, inclusive of both RACH and AGCH.

- Access attempts needed = Number of access attempts per successfully completed Immediate Assignment procedures, inclusive of both RACH and AGCH [histogram].
- Access time = Time from when an Immediate Assignment procedure is initiated by higher layers until successful completion of the said Immediate Assignment procedure, inclusive of both RACH and AGCH [50/95 percentile].
- CCCH Capacity Used = Percentage of CCCH capacity used. To be evaluated for both RACH and AGCH.

The impact on the legacy traffic shall be evaluated for both T1 and the T2 scenario as described below.

For the T1 scenario in conjunction with the legacy traffic modelled by T3, the evaluation of the Access success rate for the legacy traffic should be conducted with a time-window starting at a period in time such that all initialization effects from different random access procedures are excluded.

Furthermore, when the T2 scenario is evaluated in conjunction with the legacy traffic modelled by T3, a windowed evaluation shall be performed of the Access success rate, evaluating all legacy devices initiating their random access procedure within consecutive 10 second time-windows. The T2 peak traffic shall be initiated when the traffic load modelled by T3 has reached a stable level.

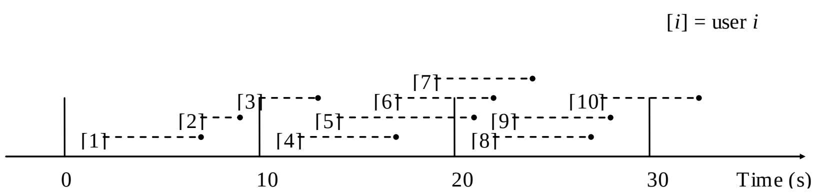

Figure 3 - Periodic evaluation of random access procedure

The statement above is clarified in Figure 3, where [*i*] denotes where device *i* initiates its Immediate Assignment procedure and the dashed line for how long period the current Immediate Assignment procedure is active. The access success rate for the first period (0 – 10 s) should be calculated for users 1, 2 and 3, even though the end of the Immediate Assignment procedure for the user is in the subsequent evaluation period. The access success rate for the second period (10 – 20 s) should be calculated for users 4, 5, 6 and 7, and the access success rate for the third period (20 – 30 s) should be calculated for users 8, 9 and 10.

Upon the windowed evaluation of the Access success rate an overall measure of the access success rate should be provided. This measure should use a time-window large enough to cover all effects from the MTC devices accesses.

The Average access success rate for the legacy CS services when MTC traffic is added shall not be significantly decreased as compared to the reference case of the T3 scenario (see sub-clause 6.1.2). The Average access success rate of legacy PS services may have some relaxation.

6.3.4 PDCH traffic output

- TBF Blocking Rate = Blocking rate due to insufficient resources (e.g. USF and TFI identifiers), which makes it impossible for the network to assign uplink PDCHs to the MTC devices. The output should be differentiated between different causes.
- MTC payload transfer delay = The time it takes for a MTC device to successfully transfer its application level payload, as from when it received its TBF assignment [50/95/99 percentile].

6.4 *<Common Assumption>*

7 Summary and conclusions

The impacts on GERAN specifications identified in sub-sections 4 and 5 shall be used as a basis for additional normative specification work.

Annex A (informative): Change history

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
2010-09-03	*47*	*GP-101629*		*-*	*TR updated with the common assumption on simulation and evaluation based on input in GP-101378*	*0.0.3*	*0.0.4*
2010-11-26	*48*	*GP-102067*		*-*	*TR updated with comments provided at and after GERAN#47.*	*0.0.4*	*0.2.0*
2011-05-11	*50*	*GP-110735*			*TR updated with additional and modified evaluation and simulation assumptions as provided to GERAN2 MTC Ad Hoc in G2-110033.*	*0.2.0*	*0.3.0*
2011-08-28	*51*	*GP-111266*			*TR updated with additional simulation assumptions regarding the PS legacy traffic.*	*0.3.0*	*0.4.0*
2011-09-02	*52*	*GP-111716*			*TR updated as per agreements made during GERAN#51.*	*0.4.0*	*0.5.0*
2012-05-17	*54*	*GP-120745*			*Inclusion of the P-CR on Conclusions on CCCH overload control*	*0.5.0*	*1.0.0*