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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 work item “LTE RAN Enhancements for Diverse Data Applications” was approved at RAN #51 and incorporates an initial evaluation phase prior to the stage 2 and stage 3 work.

This report captures the output of the initial evaluation phase.

1 Scope

The present document constitutes the output of the initial evaluation phase for the work item “LTE RAN Enhancements for Diverse Data Applications” (LTE_eDDA). The document captures agreements and descriptions related to the evaluation methodology used, descriptions of enhancement proposals and their evaluation results, and conclusions and recommendations for further work within the scope of the LTE_eDDA work item.

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] LOLA Project (Achieving Low-Latency in Wireless Communications), “D 3.3 Summary of the Traffic Measurements v1.0”. March, 2011. Available at http://www.ict-lola.eu/

[3] 3GPP TS 36.213: “E-UTRA; Physical Layer Procedures”

[4] R2-116167 “Signalling overhead of diverse data applications”, Huawei, RAN WG2 #76, San Francisco, USA, 14-18 November 2011

[5] “NGMN Radio Access Performance Evaluation Methodology”, available at http://www.ngmn.org

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].

<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].

CDF Cumulative Distribution Function

eDDA	Enhancements for Diverse Data Applications
IM	Instant Messaging
OS	Operating System
SPS	Semi-Persistent Scheduling
SR	Scheduling Request

4 Evaluation Methodology

Enhancement proposals considered as part of the LTE_eDDA work item are likely to exhibit some diversity in their focus on different application/traffic situations, and to tackle different areas of the system and its optimisation.

In order to provide the necessary degree of commonality and comparability between company results when evaluating these proposals, an evaluation framework has been established encompassing:

- Evaluation guidelines(detailed in sub-clause 4.1)
- The types of traffic to be evaluated (detailed in sub-clause 4.2)

4.1 Evaluation Guidelines

4.1.1 Traffic Sources

The following alternatives have been identified to generate source traffic for the purposes of evaluation:

Traffic Trace:	Data traffic or packets captured from live systems or apparatus running one or more applications of interest
Synthetic Models:	Abstract modelling of application-level and/or user behaviours in order to faithfully represent or emulate data traffic that would typically be observed from a live running application
Statistical Models:	Generation of data traffic or packets according to random processes governed by parameters that are themselves derived from statistics observed from one or more live running applications

- Companies may use either trace-based or synthetic/statistical model-based approaches to generate source traffic
- For trace based approaches:
  - Reasonable disclosure of the trace capture environment is required (sufficient to enable reproduction of a similar traffic scenario by another company). This should include for example, information relating to the access technologies used during the capture, any pertinent configuration details therein, the data rates of involved links, the nature of running or open applications, the degree of user interactivity with the device and the captured protocol layer
  - Key statistics of the trace shall be provided— to include at least the distributions of inter-arrival times, and packet sizes, and information regarding data rates
  - Provision of the actual trace is optional
- For model-based approaches:
  - Disclosure of the model and its parameters is required
  - Some validation of the model (i.e. verifying its alignment with real-world traces, statistics or behaviours) shall be provided
- To help improve alignment between company evaluations, the guideline traffic scenarios of sub-clause 4.2 have been created. Companies are encouraged to use traces or models whose statistical properties conform to (or are

closely consistent with) those listed for the guideline traffic scenarios, although the use of other traffic scenarios for evaluation purposes is not precluded.

4.1.2 Simulation Environment

- For the purposes of simulation, a suitable abstraction of the physical layer is permitted (it need not be explicitly modelled). Where appropriate, basic HARQ functionality at the sub-frame level should be included.
- Depending on the nature of the proposal, some evaluations may require that TCP is modelled. Evaluations shall state whether or not this has been performed and provide reasons. TCP modelling may apply to either traffic models or to trace-based traffic. A simplified TCP model may be used, sufficient to capture slow-start and congestion avoidance effects.
- When submitting proposals, companies should consider whether there are any potential impacts to mobility. If significant mobility aspects are identified, evaluations regarding those impacts should also be provided.
- Where appropriate, assumptions on how the network's RRC state control mechanisms operate shall be stated.

4.1.3 Output Metrics

Metrics of interest are dependent on the nature of a particular proposal. However, the following guidelines regarding output metrics are recommended. It is expected that wherever there is perceived to be a significant impact to one of the areas covered by these metrics, the associated metric(s) will be provided and the guidelines followed.

- **UE power consumption (for the radio communications part)**
  - This may further comprise (or be related to) associated metrics such as active time and active time utilisation
  - The power consumption effects of RRC state transitions and mobility should be taken into account
  - Power consumption may be expressed in absolute terms or relative to a baseline power consumption value. Depending on the particular proposal, the baseline power consumption value may be for example that of RRC_IDLE or that of the system with/without implementation of a particular enhancement
  - Parameters that affect power consumption and which are configured by the network shall be stated, along with any associated assumptions
- **Overheads and Signalling**
  - Signalling costs should be evaluated
  - System resource overheads (e.g. in terms of number or fraction of assigned/used/reserved control channel resources and RBs) should be considered
  - Effects on RRC state transition frequency and on handover frequency should be reported where appropriate
  - Effects on the average time spent in connected mode (vs. idle) should be reported where appropriate. Note that the average time spent in connected mode can also be used to derive the impacts on the number of simultaneous RRC connections required within a cell or eNB site.
- **User Visible Metrics / QoS**
  - Latency: Impacts or benefits to latency shall be provided, in the form of latency distributions, percentiles or bounds.
  - Throughput: Impacts or benefits to throughput shall be provided, in the form of throughput distributions, percentiles or bounds.
  - The data unit size (e.g. web-page, IP datagram, MAC PDU etc..) used to represent the latency and throughput metrics and distributions shall be stated.
  - If the proposal relates to differing levels of QoS, metrics associated with each of the different QoS levels shall be provided.

4.2 Traffic Scenarios and Characterisation

The following traffic scenarios provide the primary focus for the evaluations. The emphasis is on smartphone and tablet device types (rather than PCs).

Table 4.2-1: Traffic scenarios

Label	Traffic Scenario	Description
Top priority		
A	Background Traffic	Traffic from an unattended phone with applications not in "active phase" (i.e. not including email retrieval, no IM sending etc…)
B	IM	Instant Messaging. Includes IM background traffic.
Non-top-priority		
C	Gaming	Use of on-line interactive games
D	Interactive Content Pull	User-interactive web browsing, online maps, social network browsing, application store / music store browsing and other similar content pull by the user
E	HTTP Video Streaming	Segment-oriented transfer of video media

A statistical characterisation of each of these traffic scenarios is provided in sub-clauses 4.2.1 through 4.2.5 respectively.

4.2.1 A) Background Traffic

Background traffic refers to the autonomous exchange of user plane data packets between the UE and the network, generally in the absence of a specific user interaction with the device. The packets often arise due to open applications (or processes that remain resident in the device memory) which require communication on a regular or intermittent basis with peer entities within the network.

The traffic is generally low in volume (i.e. it has a low mean data rate) and comprises packets that may be widely dispersed in time. In observed scenarios with a relatively small number of open background applications and processes on a typical device, the mean volume of data (aggregated uplink plus downlink) ranges from approximately 5 Bytes/s through to approximately 250 Bytes/s.

Keep-alive behaviours may be present, in which case the observed packet inter-arrival durations will display an upper limit. The exact characteristics of the traffic vary as a function of the particular applications that are running.

Due to the range of application behaviours, significant variations in the observed statistics are seen. Background traffic (in the case where one or more background data applications are running) may therefore be divided into two categories: "light background" and "heavier background" respectively. Light background traffic corresponds to generally lower mean data rates and a lower mean number of packets per second. Light background traffic also has less clustering of packets. In the figures that follow, this aspect has been used to help differentiate between light and heavier background cases:

- Light Background: Traces for which the packet inter-arrival CDFs lie mainly to the right of a straight line drawn from 25% at 100ms through to 75% at 10secs (on a plot with logarithmic X-axis and linear Y-axis)

- Heavier Background: Traces for which the packet inter-arrival CDFs lie mainly to the left of a line drawn from 25% at 100ms through to 75% at 10secs (on a plot with logarithmic X-axis and linear Y-axis)

In addition, a trace of traffic generated in the absence of any background data applications (i.e. data related to the operating system only), has been captured. This is referred to below as OS-only traffic.

<u>Light Background</u>

Figures 4.2.1-1 through 4.2.1-4 show downlink and uplink cumulative distributions of packet inter-arrival times for several recorded light background traffic traces. Figures 4.2.1-5 and 4.2.1-6 show the corresponding cumulative distributions of the IP packet sizes (including IP headers).

Traces are indexed by their Trace-ID. A list of Trace-IDs may be found in Appendix A.1.

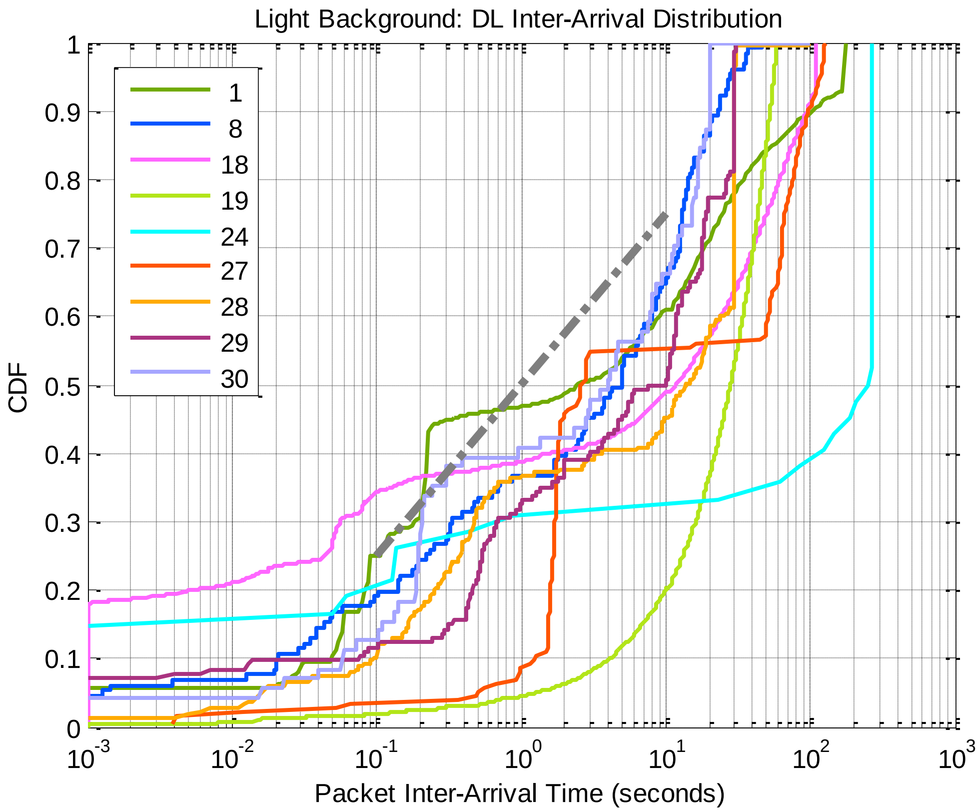

Figure 4.2.1-1: Light Background Traffic - Packet Inter-Arrival Time CDFs (downlink)

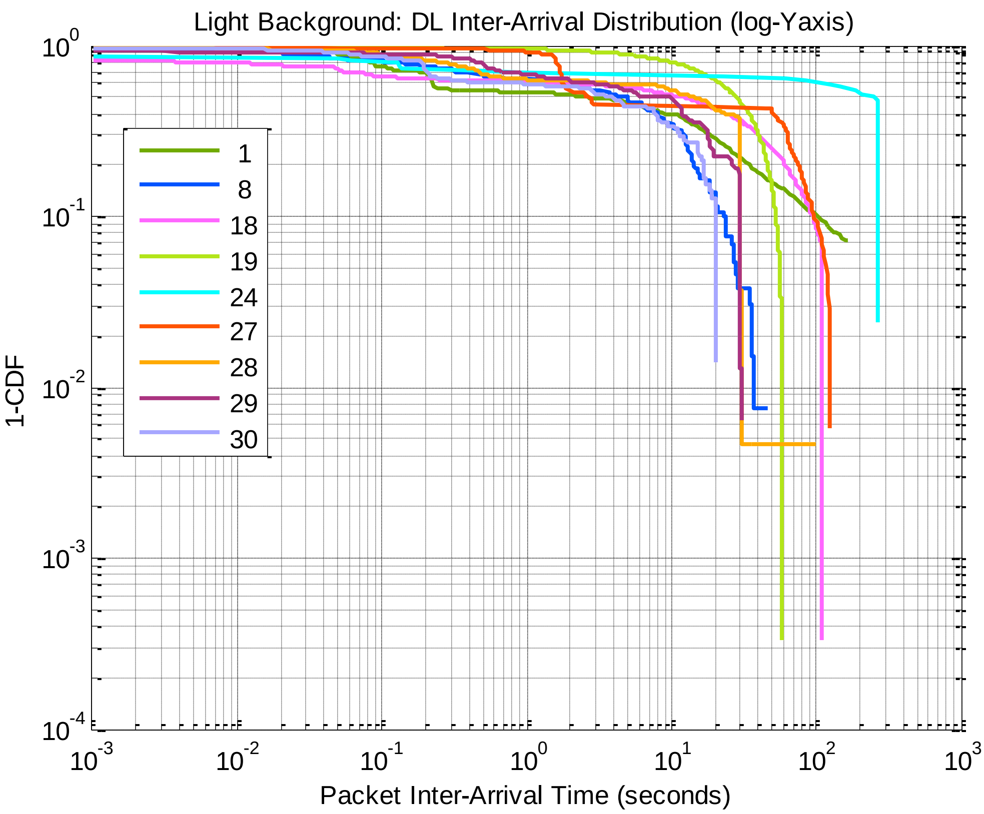

Figure 4.2.1-2: Light Background Traffic - Packet Inter-Arrival Time CDFs (downlink – log Y axis)

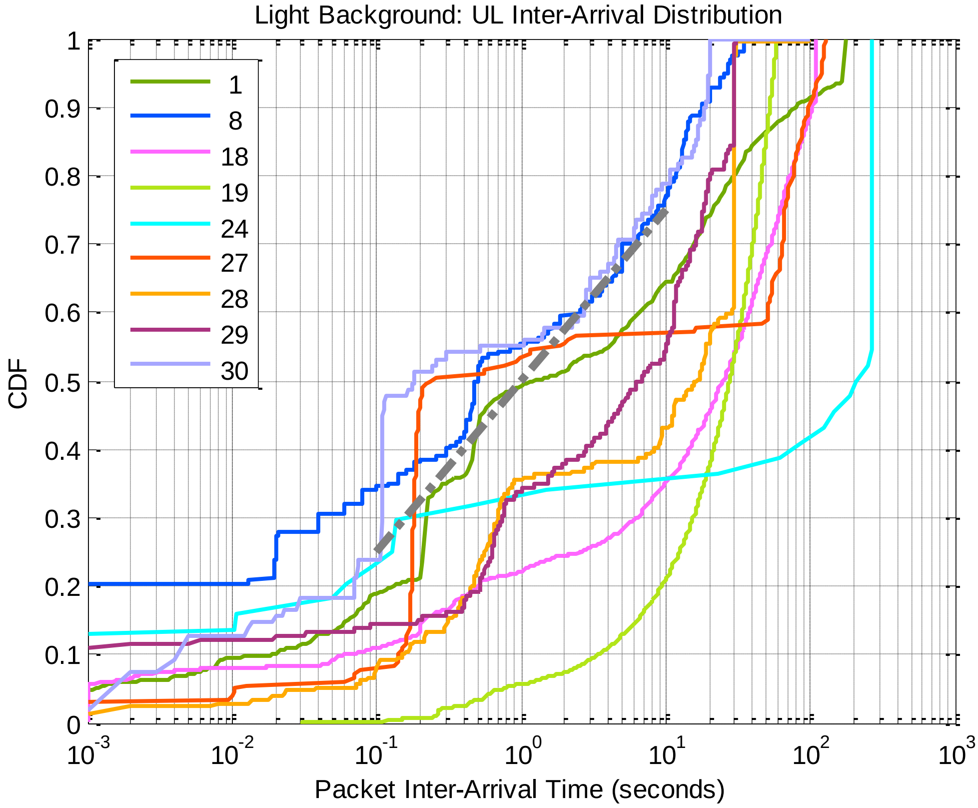

Figure 4.2.1-3: Light Background Traffic - Packet Inter-Arrival Time CDFs (uplink)

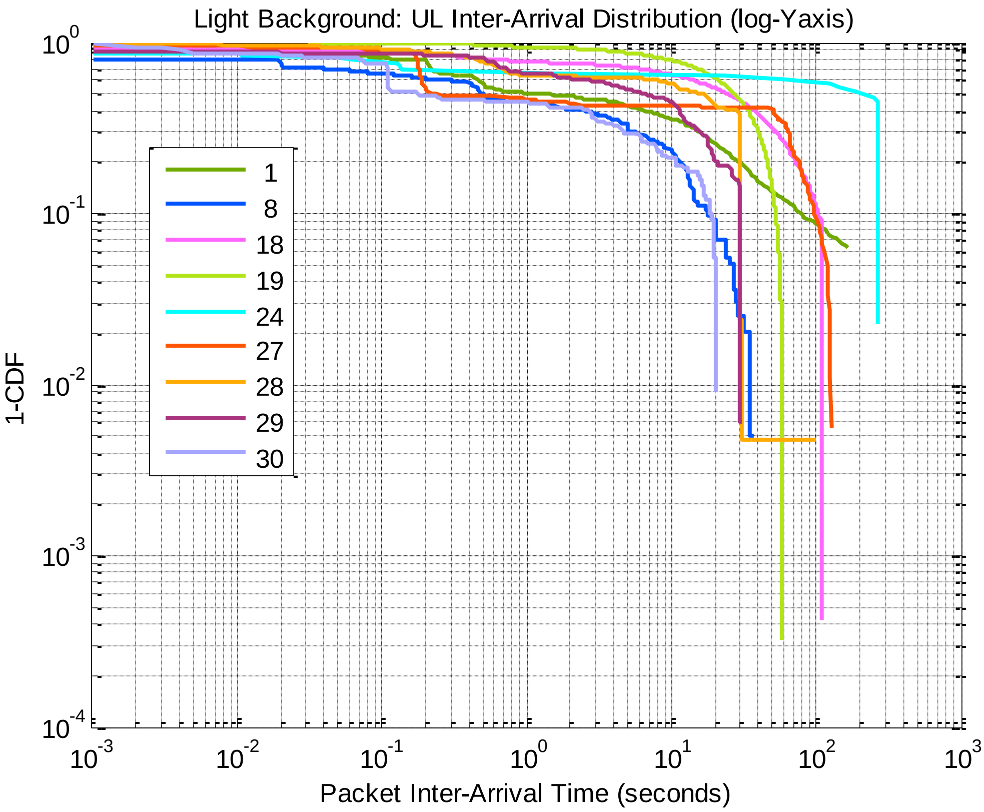

Figure 4.2.1-4: Light Background Traffic - Packet Inter-Arrival Time CDFs (uplink – log Y axis)

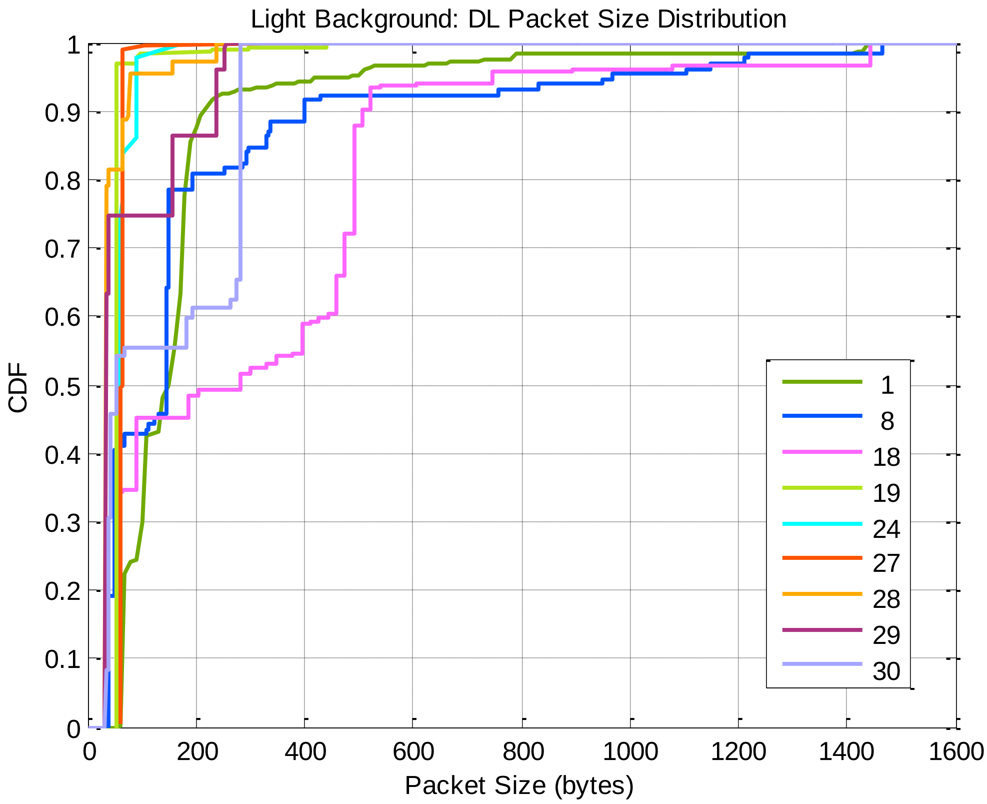

Figure 4.2.1-5: Light Background Traffic - Packet Size CDFs (downlink)

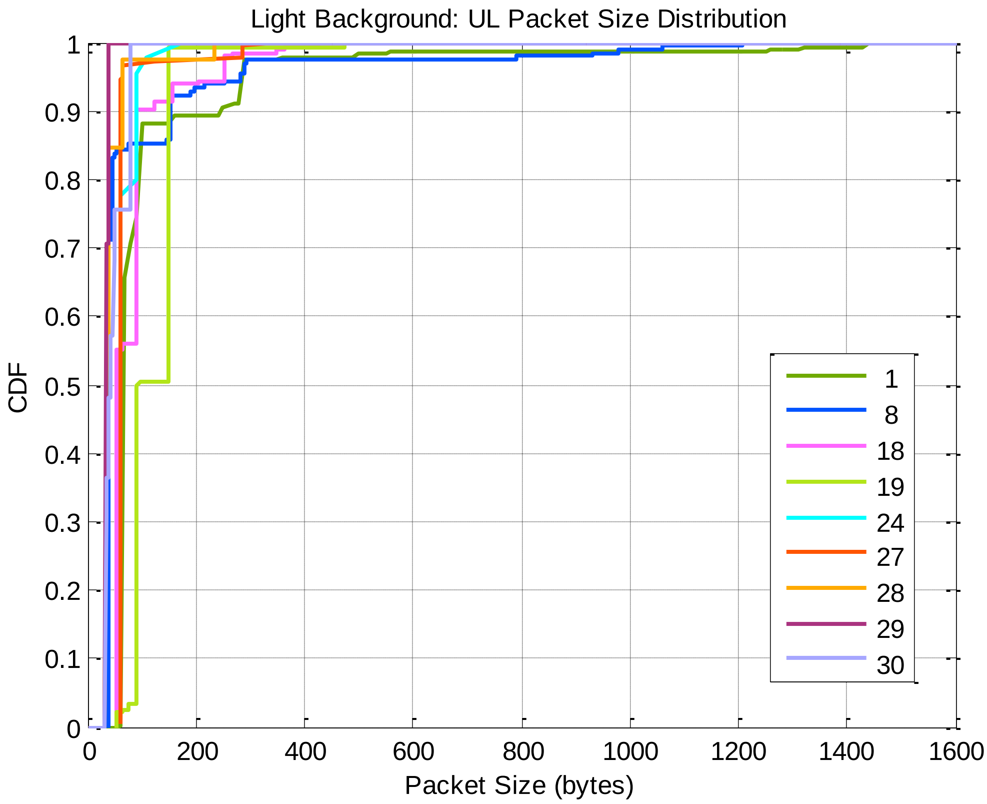

Figure 4.2.1-6: Light Background Traffic - Packet Size CDFs (uplink)

Heavier Background

Figures 4.2.1-7 through 4.2.1-10 show downlink and uplink cumulative distributions of packet inter-arrival times for several recorded heavier background traffic traces. Figures 4.2.1-11 and 4.2.1-12 show the corresponding cumulative distributions of the IP packet sizes (including IP headers).

Traces are indexed by their Trace-ID. A list of Trace-IDs may be found in Appendix A.1.

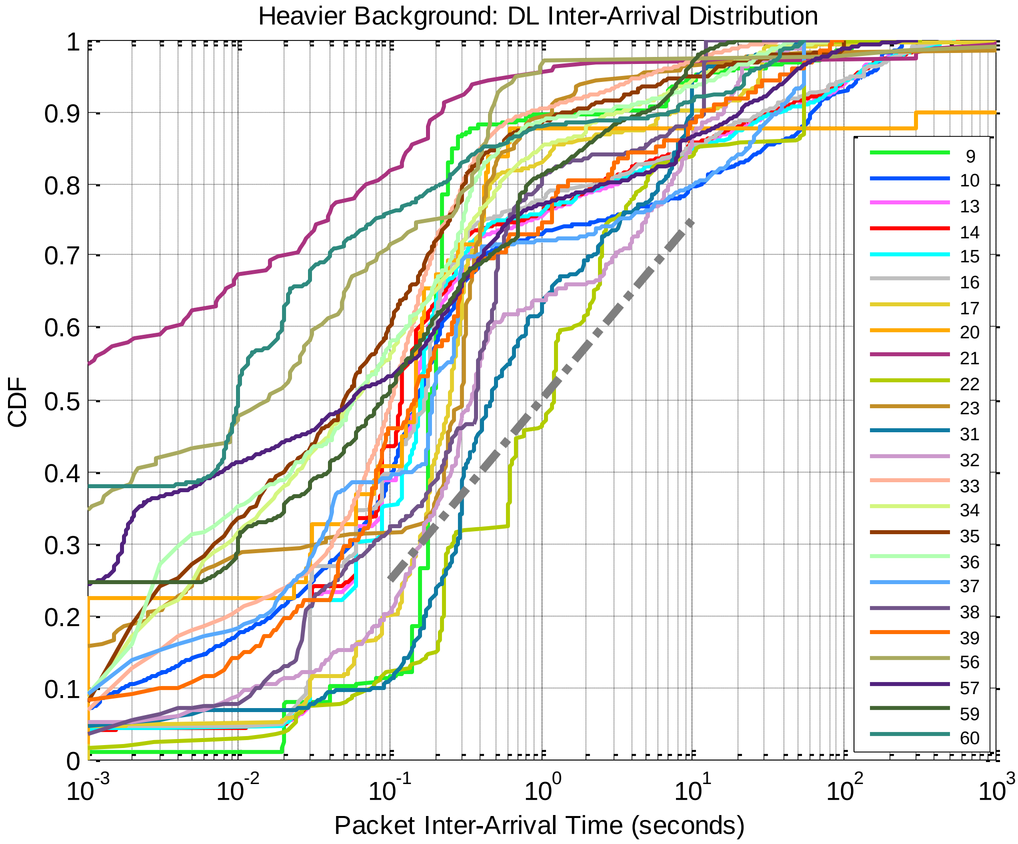

Figure 4.2.1-7: Heavier Background Traffic - Packet Inter-Arrival Time CDFs (downlink)

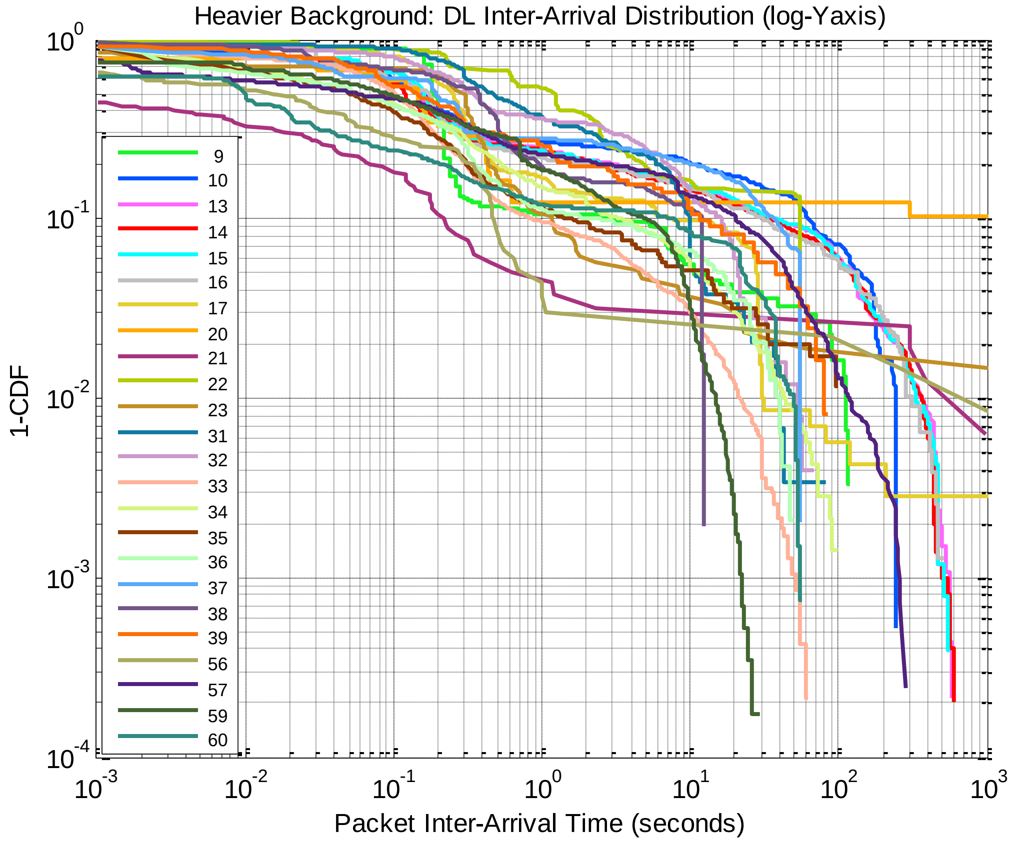

Figure 4.2.1-8: Heavier Background Traffic - Packet Inter-Arrival Time CDFs (downlink – log Y axis)

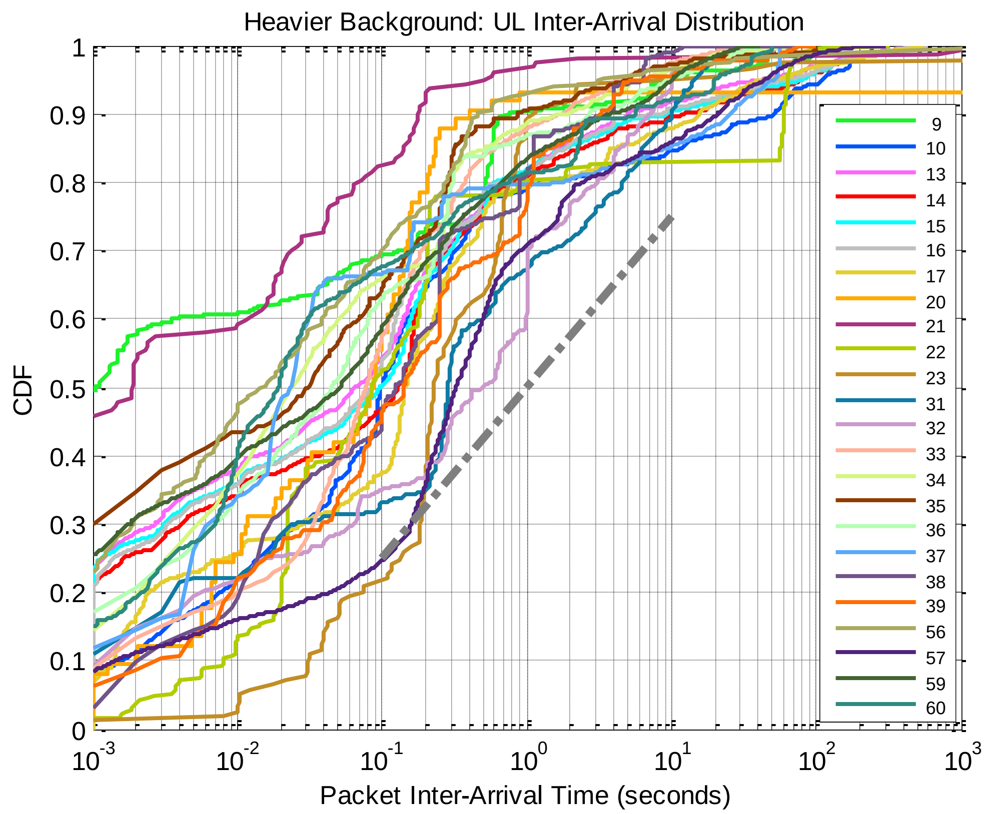

Figure 4.2.1-9: Heavier Background Traffic - Packet Inter-Arrival Time CDFs (uplink)

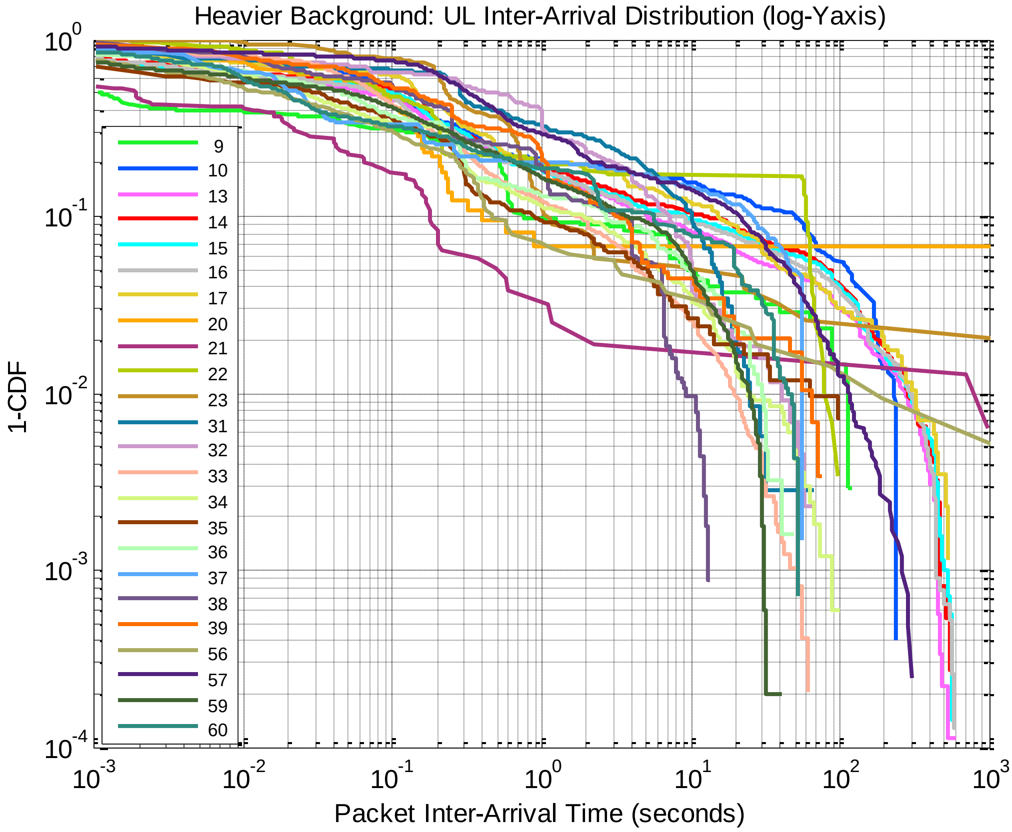

Figure 4.2.1-10: Heavier Background Traffic - Packet Inter-Arrival Time CDFs (uplink – log Y axis)

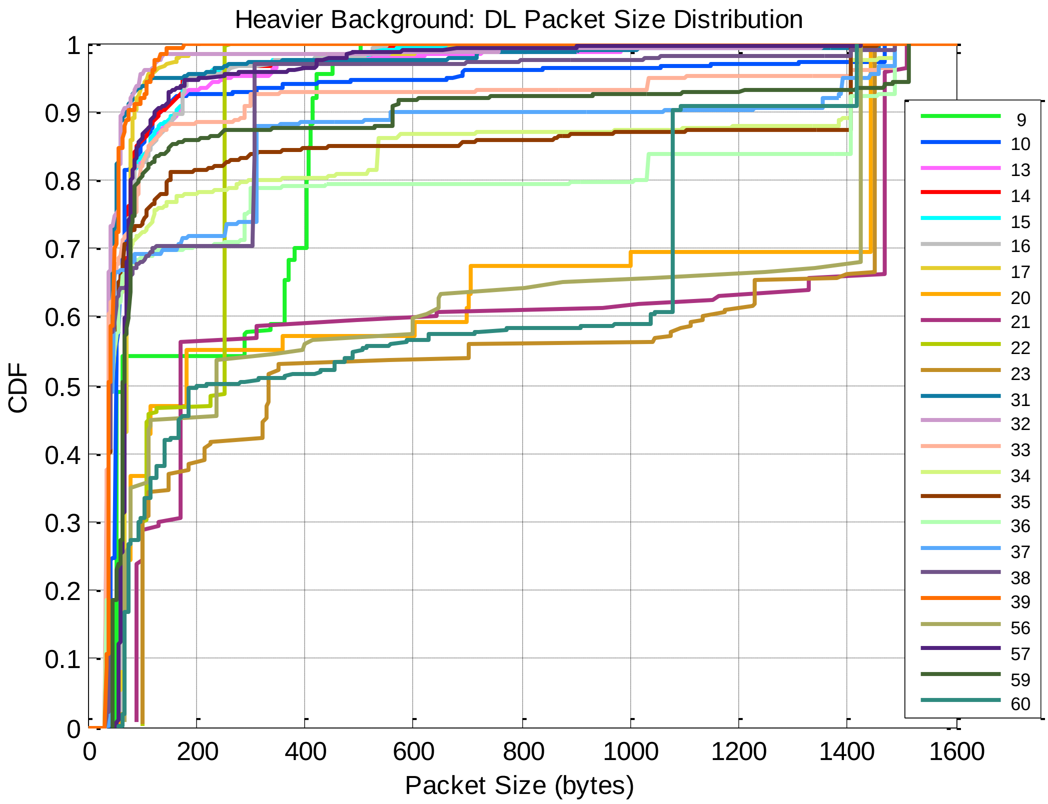

Figure 4.2.1-11: Heavier Background Traffic - Packet Size CDFs (downlink)

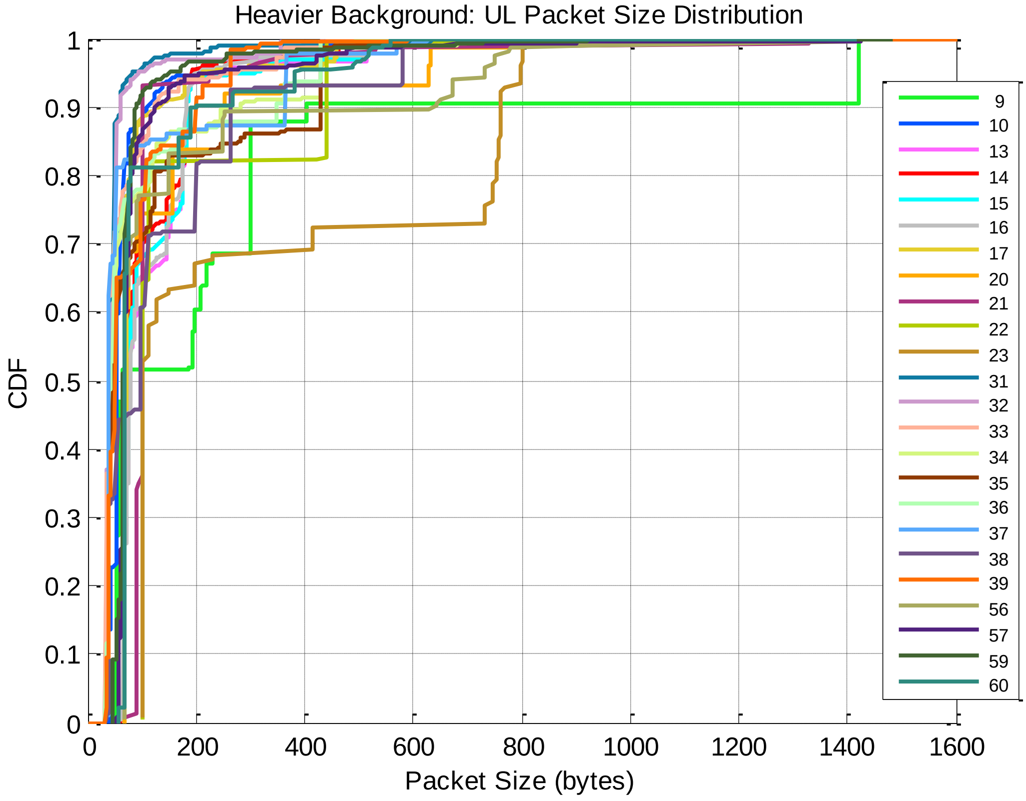

Figure 4.2.1-12: Heavier Background Traffic - Packet Size CDFs (uplink)

<u>Background – OS only (no applications)</u>

One investigation into traffic associated with a particular version of an operating system (and excluding any traffic associated with background applications) determined that a keep-alive sequence of 3 packets (2 uplink and 1 downlink) was exchanged within a burst approximately every 28 minutes. The burst size totalled 206 bytes and the burst duration was observed to be less than 2 seconds. Figures 4.2.1-13a and 4.2.1-13b show the respective cumulative distributions of packet inter-arrival times and packet sizes, corresponding to trace ID 61 of table A.1-1.

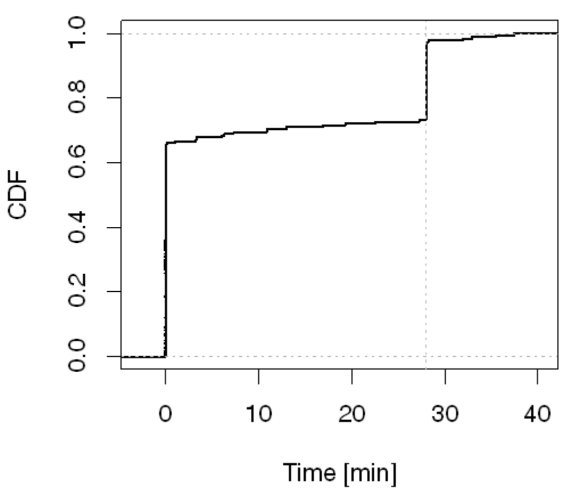

Figure 4.2.1-13a: OS-only traffic, Inter-Arrival Time

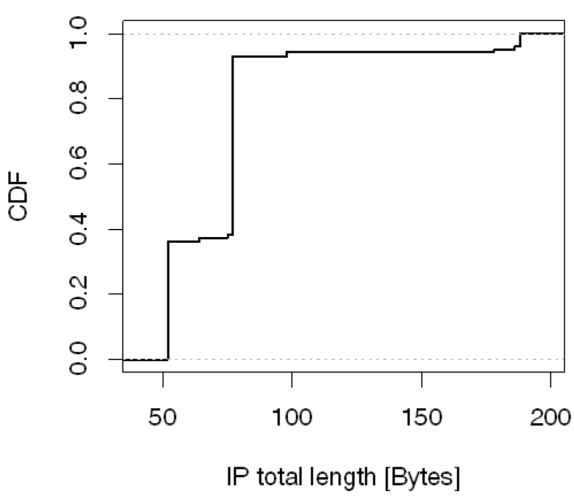

Figure 4.2.1-13b: OS-only traffic, Packet Size

4.2.2 B) Instant Messaging

Instant messaging traffic comprises a mix of user plane packets conveying the text data, along with application layer and/or transport layer protocol signalling to verify message delivery status. Some instant messaging applications may also display keep-alive behaviours and may generate other background traffic specific to the application.

The mean data rate of the traffic most commonly lies within a range of 30 - 100 Bytes/s (for aggregated uplink plus downlink).

Figures 4.2.2-1 through 4.2.2-4 show downlink and uplink cumulative distributions of packet inter-arrival times for several recorded IM traces. Figures 4.2.2-5 and 4.2.2-6 show the corresponding cumulative distributions of the IP packet sizes (including IP headers).

Traces are indexed by their Trace-ID. A list of Trace-IDs may be found in Appendix A.1.

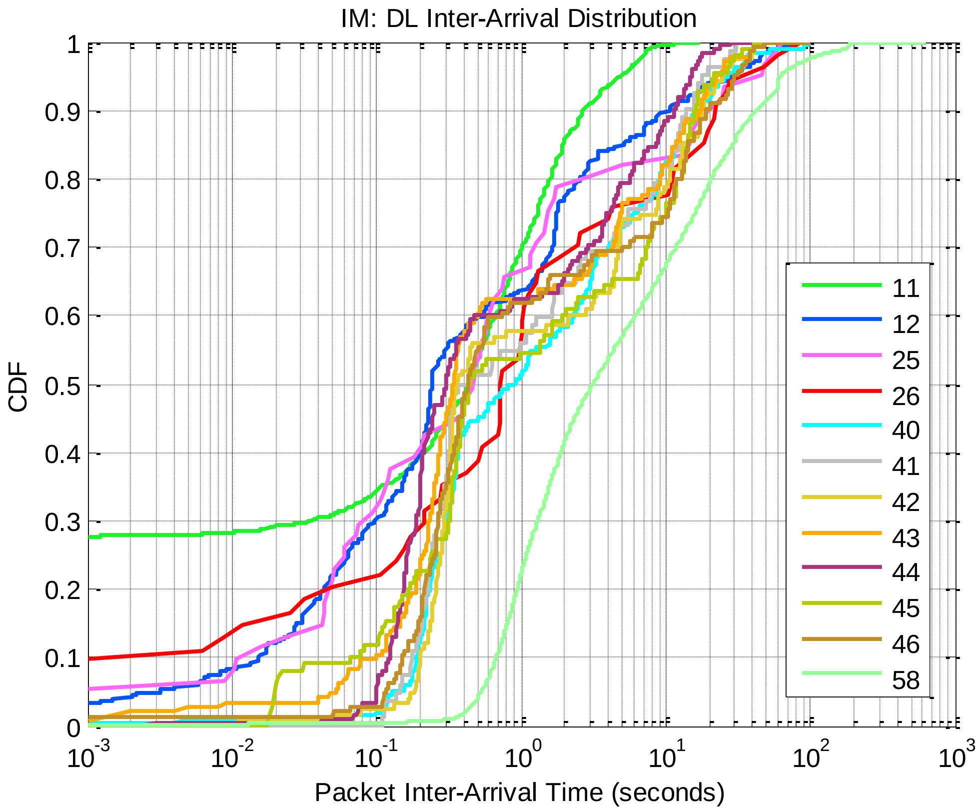

Figure 4.2.2-1: IM Traffic - Packet Inter-Arrival Time CDFs (downlink)

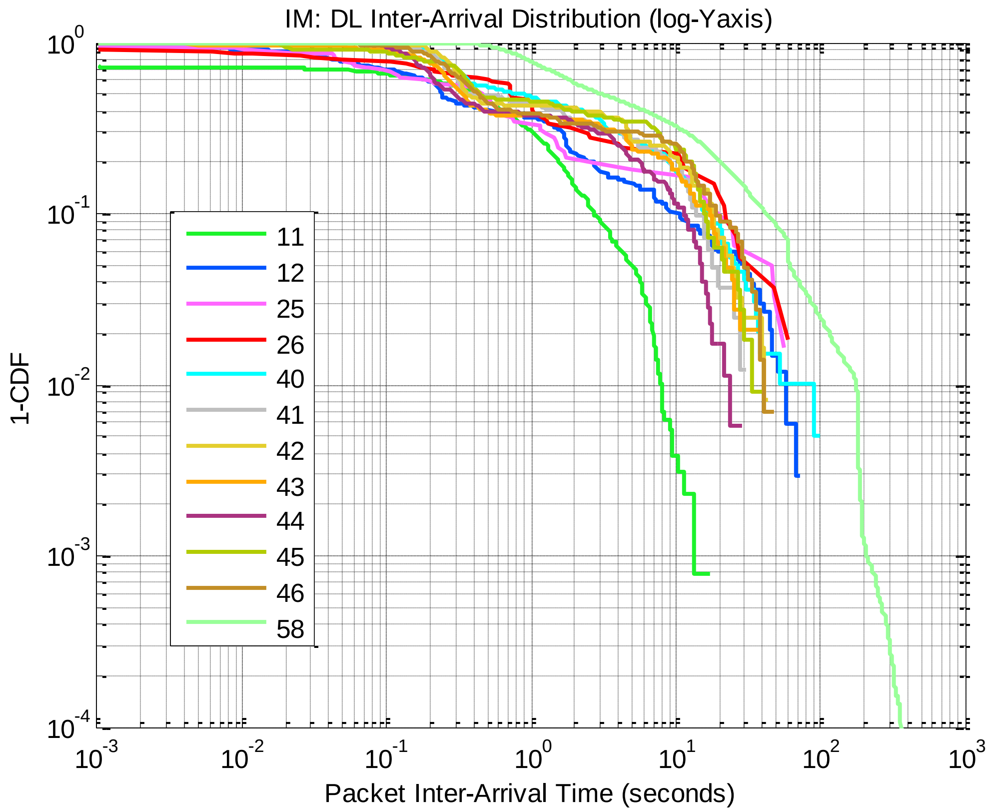

Figure 4.2.2-2: IM Traffic - Packet Inter-Arrival Time CDFs (downlink – log Y axis)

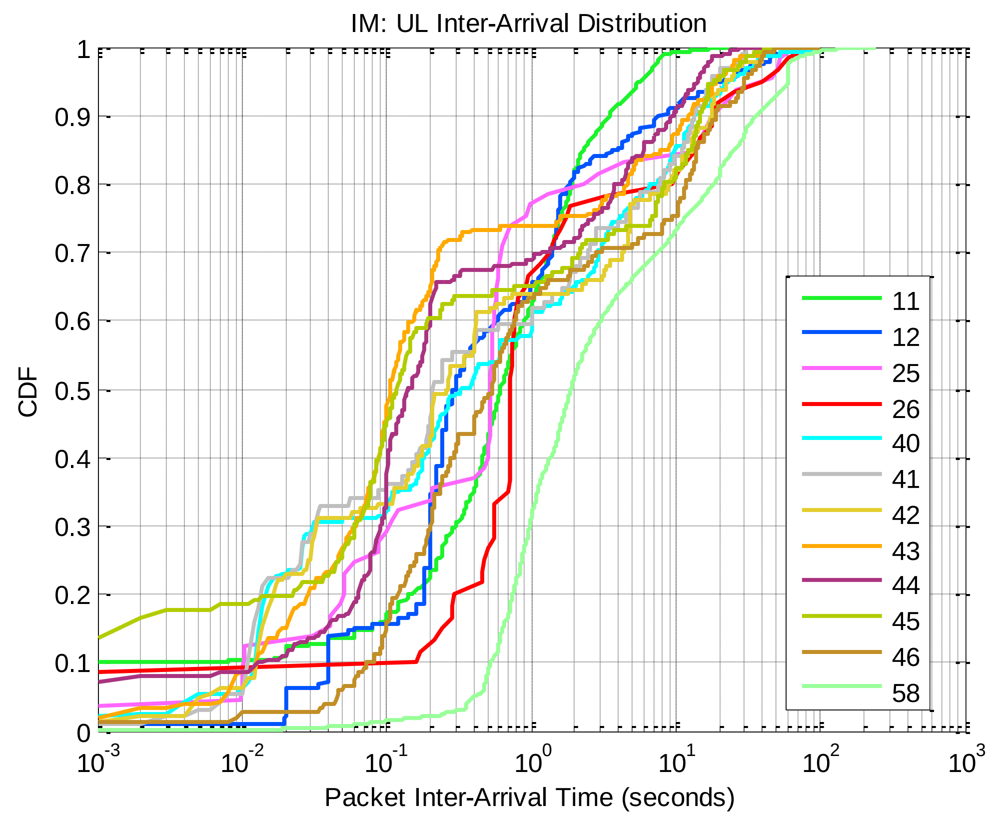

Figure 4.2.2-3: IM Traffic - Packet Inter-Arrival Time CDFs (uplink)

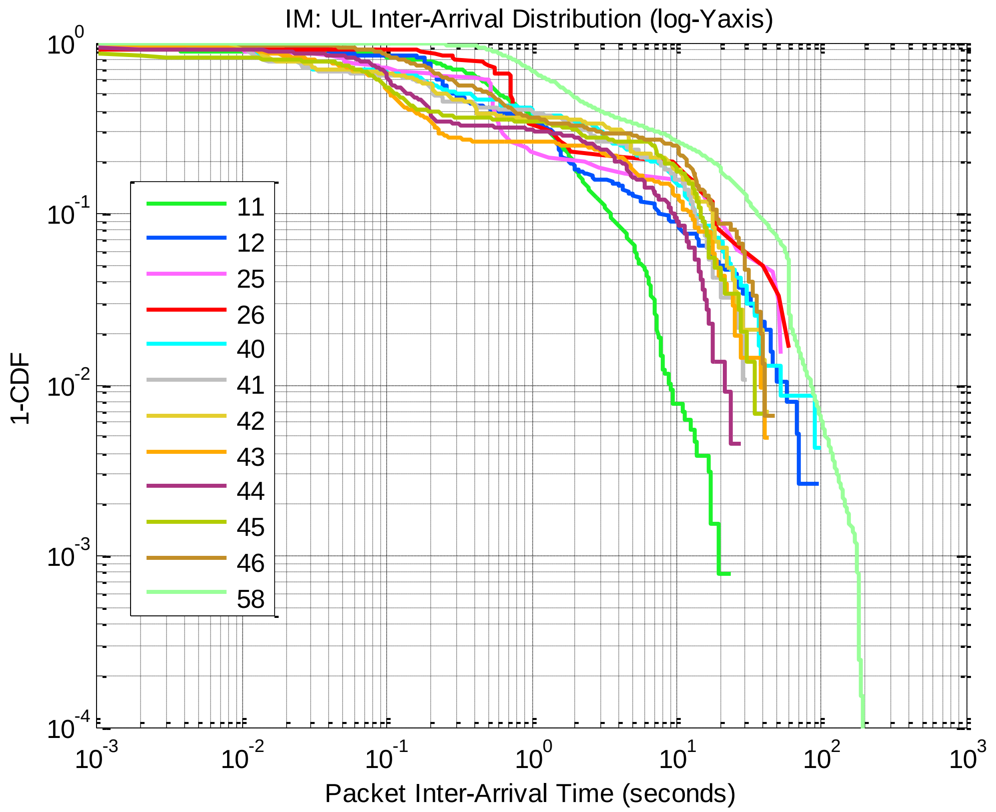

Figure 4.2.2-4: IM Traffic - Packet Inter-Arrival Time CDFs (uplink – log Y axis)

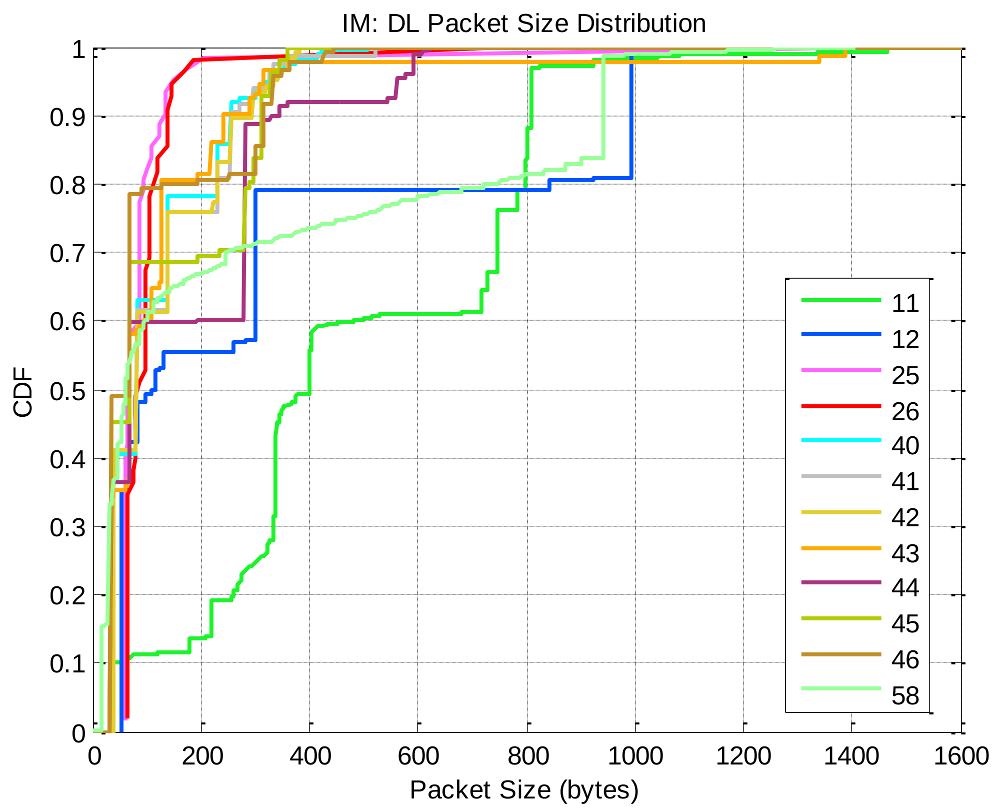

Figure 4.2.2-5: IM Traffic - Packet Size CDFs (downlink)

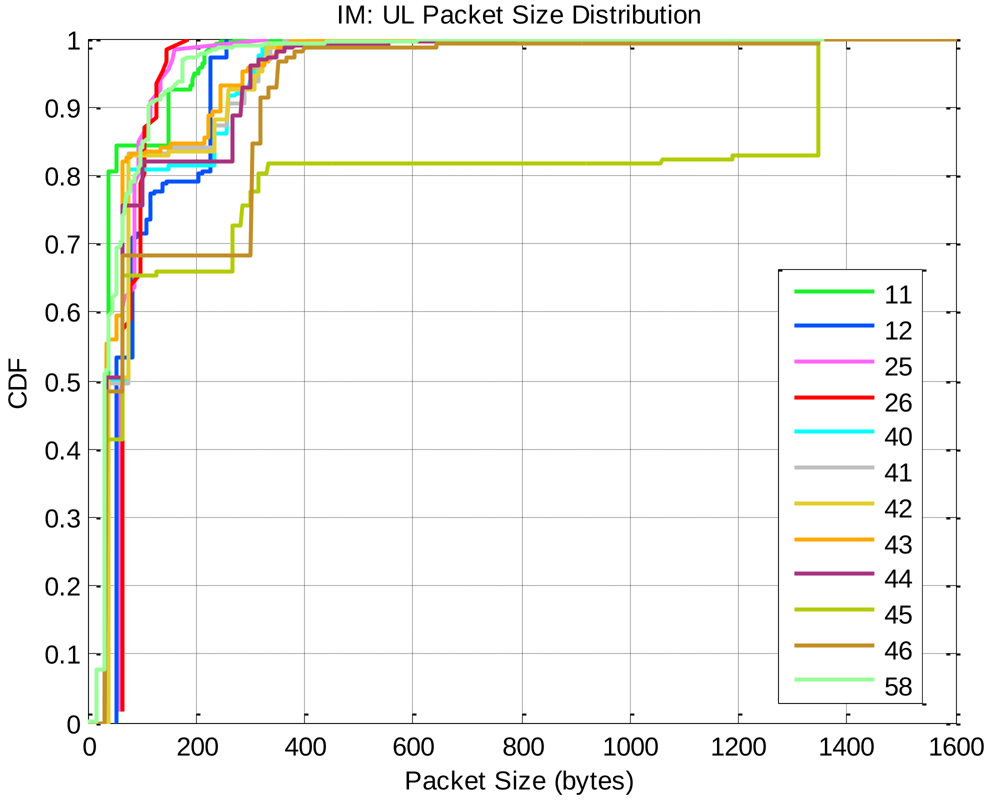

Figure 4.2.2-6: IM Traffic - Packet Size CDFs (uplink)

4.2.3 C) Gaming

Gaming traffic comprises data packets exchanged between a gaming device under user control and the network (e.g. with a gaming server).

The mean data rate of the observed traffic lies within an approximate range of 1 – 8 KBytes/s (for aggregated uplink plus downlink).

Figures 4.2.3-1 through 4.2.3-4 show downlink and uplink cumulative distributions of packet inter-arrival times for several recorded gaming traces. Figures 4.2.3-5 and 4.2.3-6 show the corresponding cumulative distributions of the IP packet sizes (including IP headers).

Traces are indexed by their Trace-ID. A list of Trace-IDs may be found in Appendix A.1 (a brief description of the games is also provided). Statistics related to Trace-IDs 5, 6, and 7 are derived from [2].

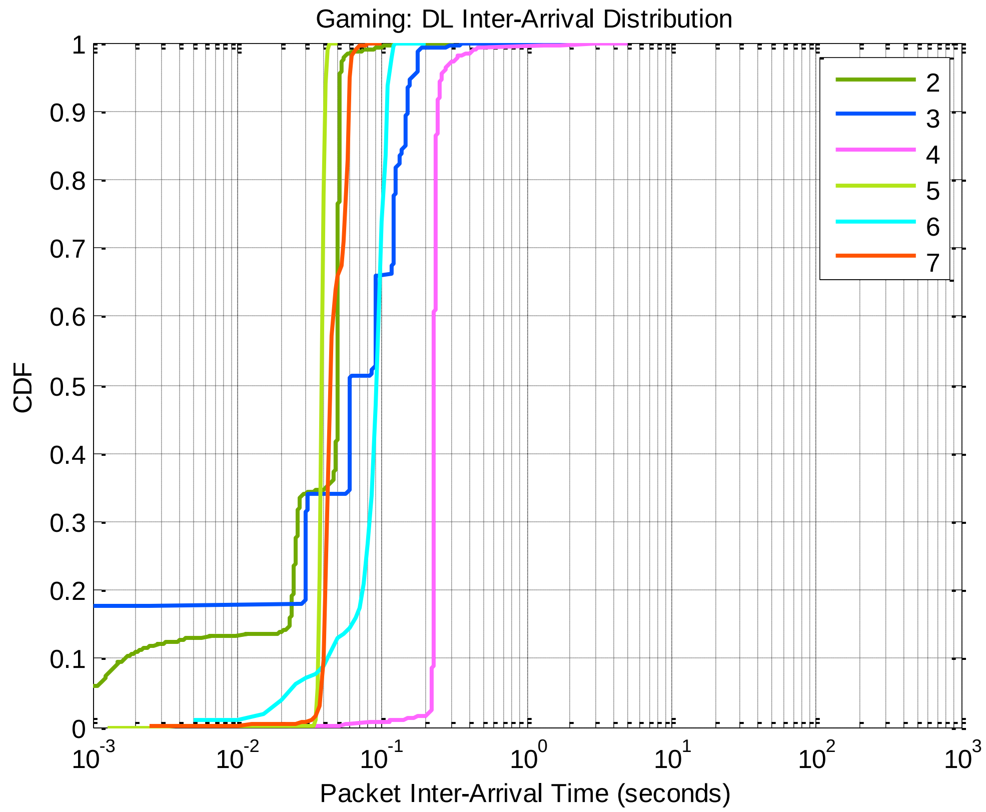

Figure 4.2.3-1: Gaming Traffic - Packet Inter-Arrival Time CDFs (downlink)

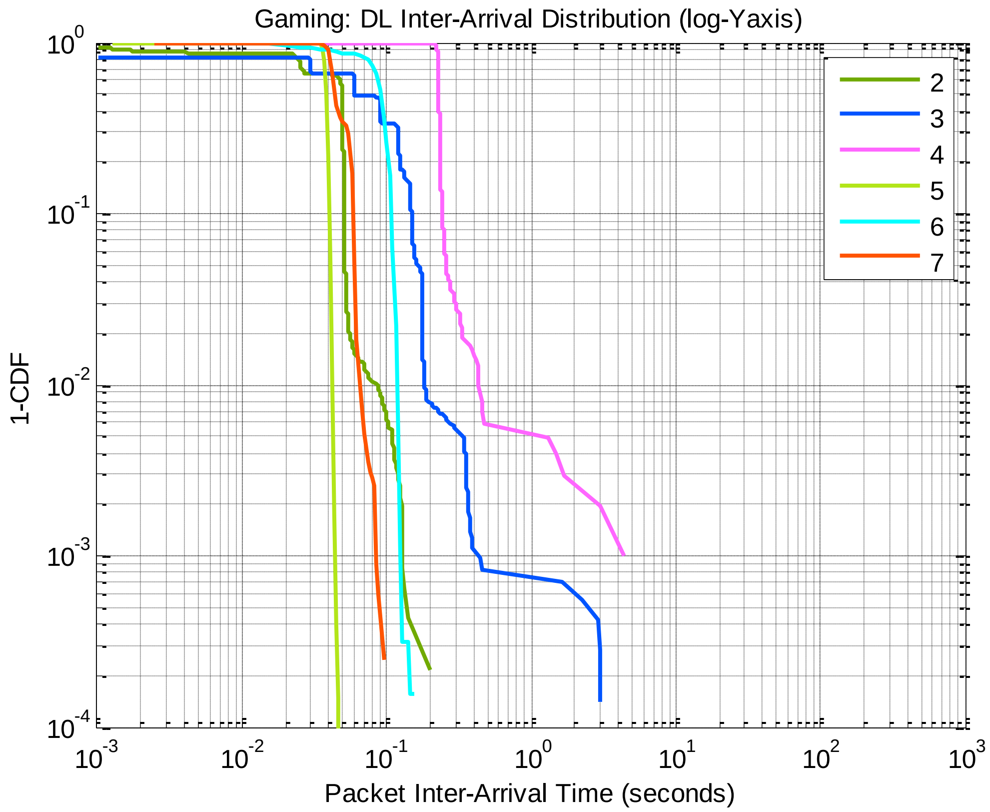

Figure 4.2.3-2: Gaming Traffic - Packet Inter-Arrival Time CDFs (downlink – log Y axis)

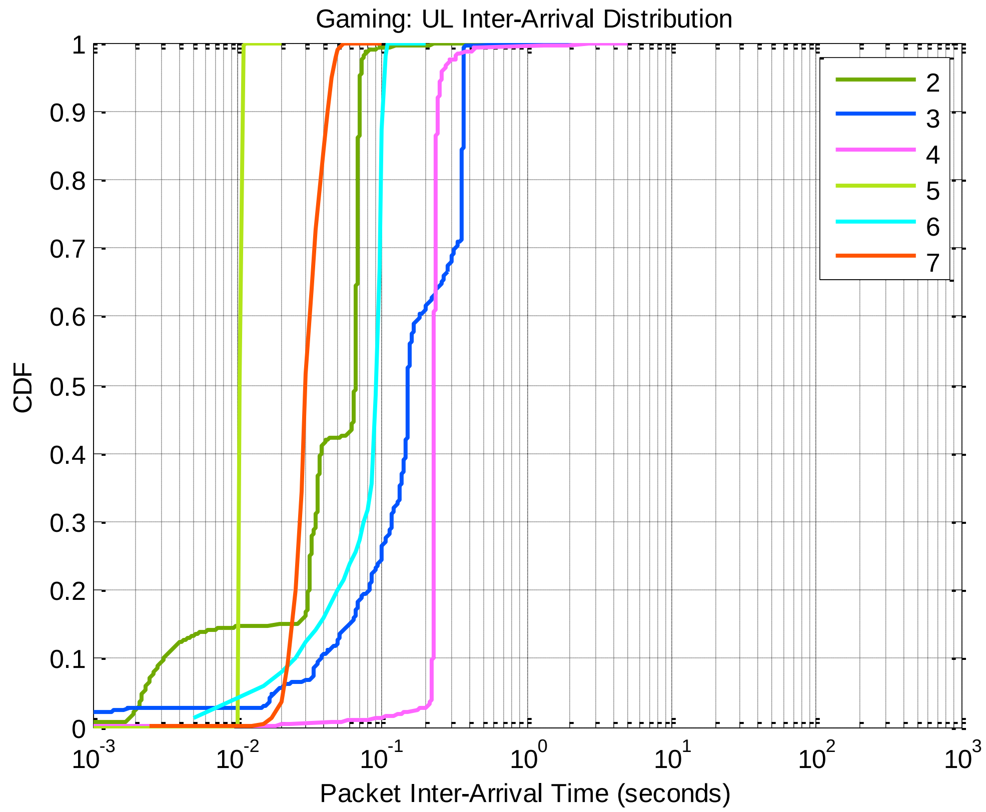

Figure 4.2.3-3: Gaming Traffic - Packet Inter-Arrival Time CDFs (uplink)

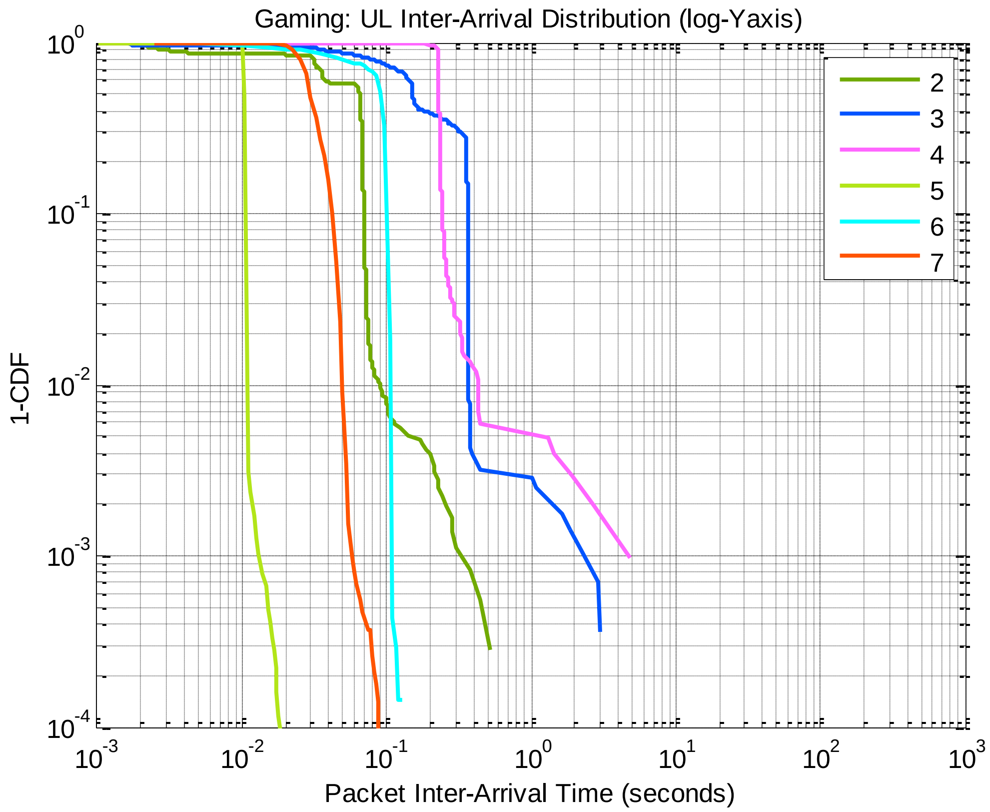

Figure 4.2.3-4: Gaming Traffic - Packet Inter-Arrival Time CDFs (uplink – log Y axis)

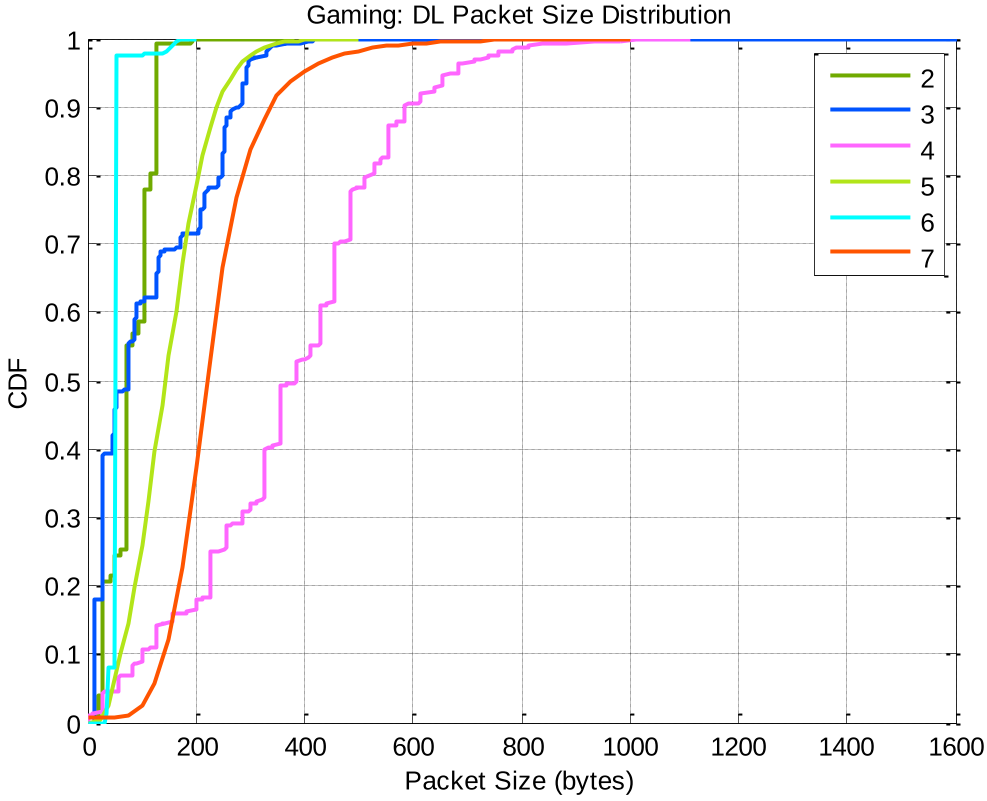

Figure 4.2.3-5: Gaming Traffic - Packet Size CDFs (downlink)

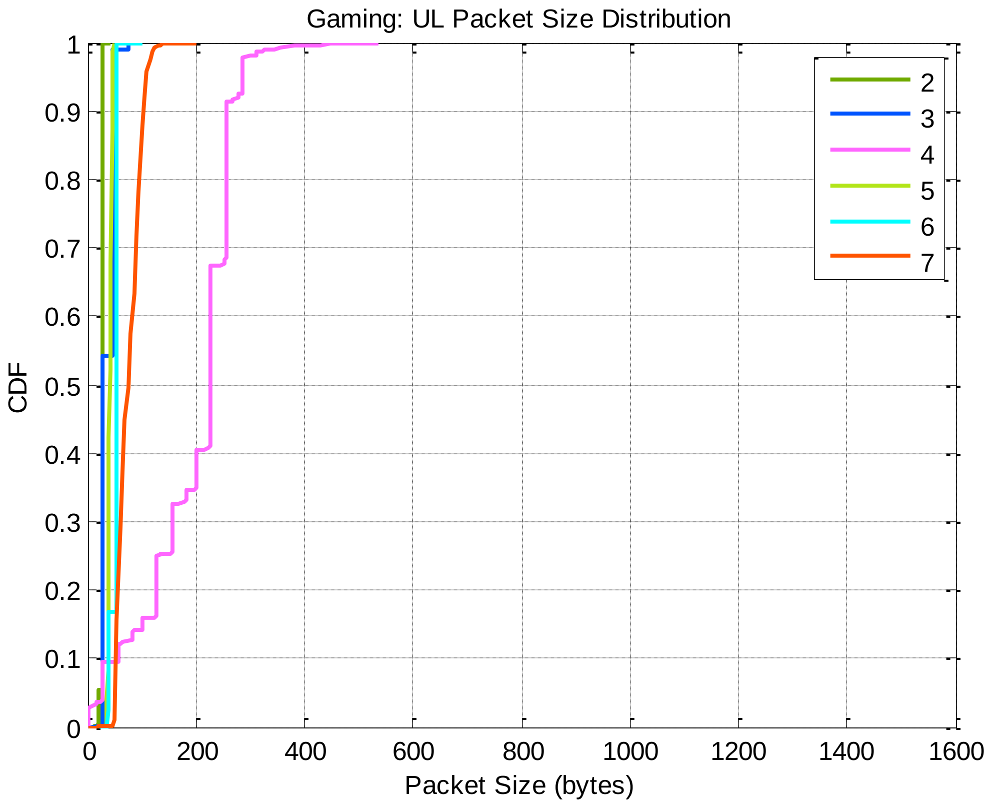

Figure 4.2.3-6: Gaming Traffic - Packet Size CDFs (uplink)

4.2.4 D) Interactive Content Pull

Interactive content pull traffic covers a relatively wide range of usage scenarios in which the user is actively browsing for, and consuming, content via browsers or other web-centric or browser-embedded technologies and applications. These may include for example HTTP web browsing, usage of online maps, browsing of social networking pages, usage of application stores and occasional download/playback of portions of audio or video media content.

The traffic has a relatively high mean data rate, with observed traces exhibiting between approximately 5 KBytes/s and 64 KBytes/s (for aggregated uplink plus downlink).

Figures 4.2.4-1 through 4.2.4-4 show downlink and uplink cumulative distributions of packet inter-arrival times for several recorded content-pull traces. Figures 4.2.4-5 and 4.2.4-6 show the corresponding cumulative distributions of the IP packet sizes (including IP headers).

Traces are indexed by their Trace-ID. A list of Trace-IDs may be found in Appendix A.1.

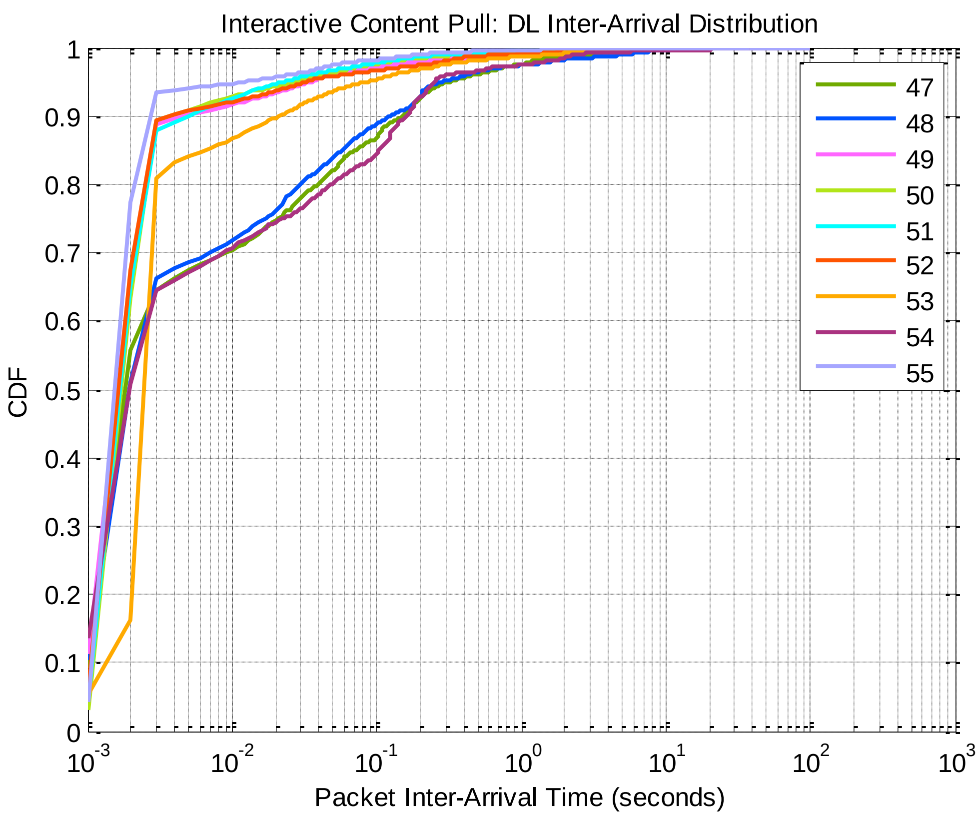

Figure 4.2.4-1: Interactive Content Pull Traffic - Packet Inter-Arrival Time CDFs (downlink)

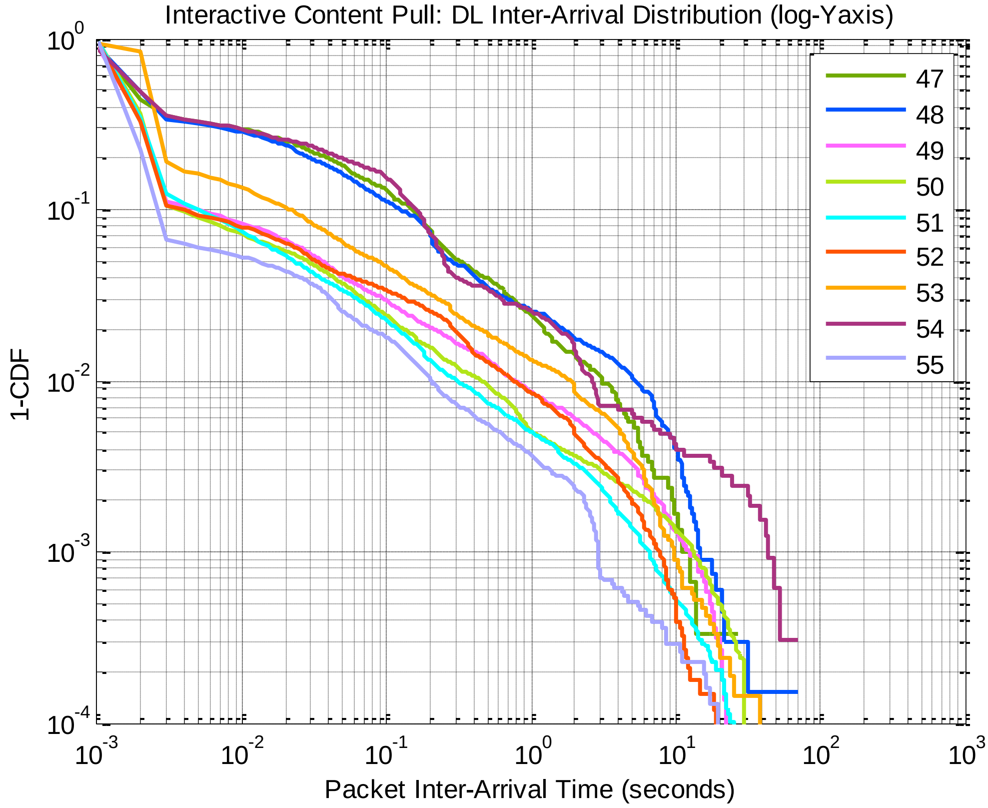

Figure 4.2.4-2: Interactive Content Pull Traffic - Packet Inter-Arrival Time CDFs (downlink – log Y axis)

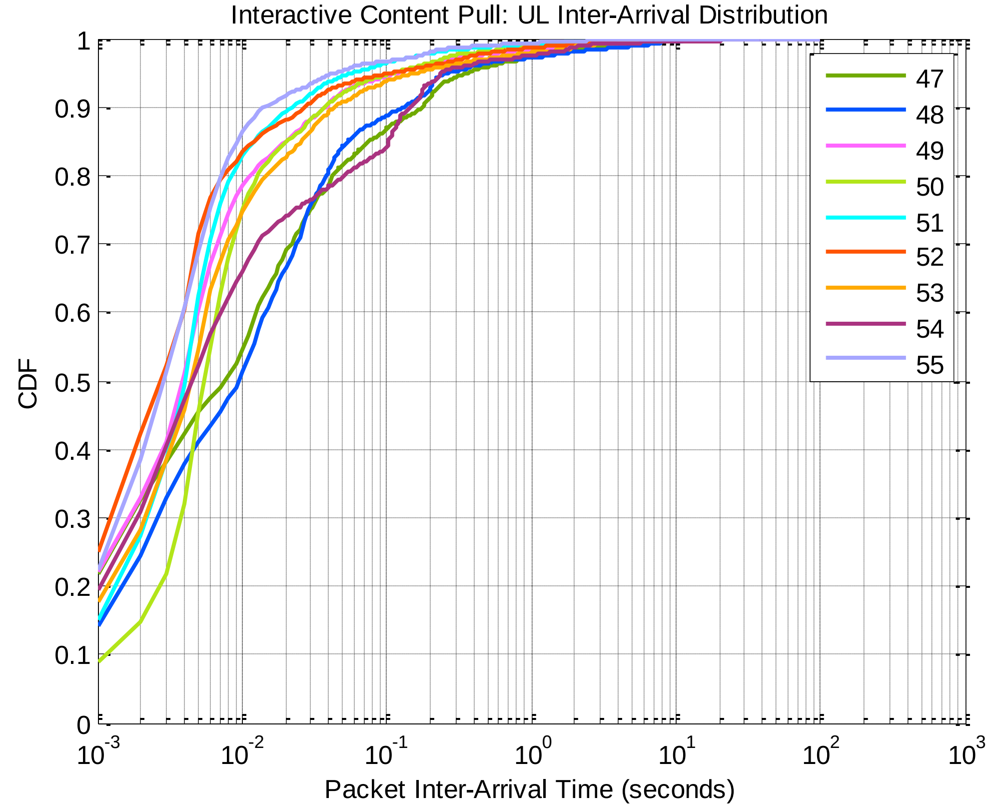

Figure 4.2.4-3: Interactive Content Pull Traffic - Packet Inter-Arrival Time CDFs (uplink)

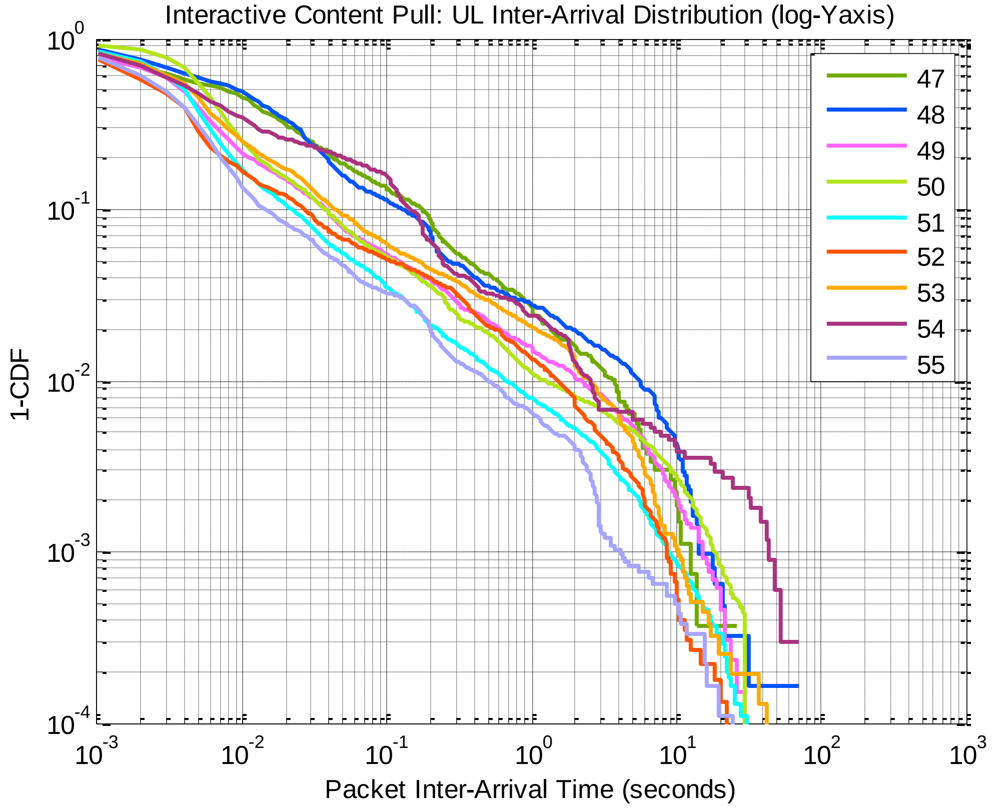

Figure 4.2.4-4: Interactive Content Pull Traffic - Packet Inter-Arrival Time CDFs (uplink – log Y axis)

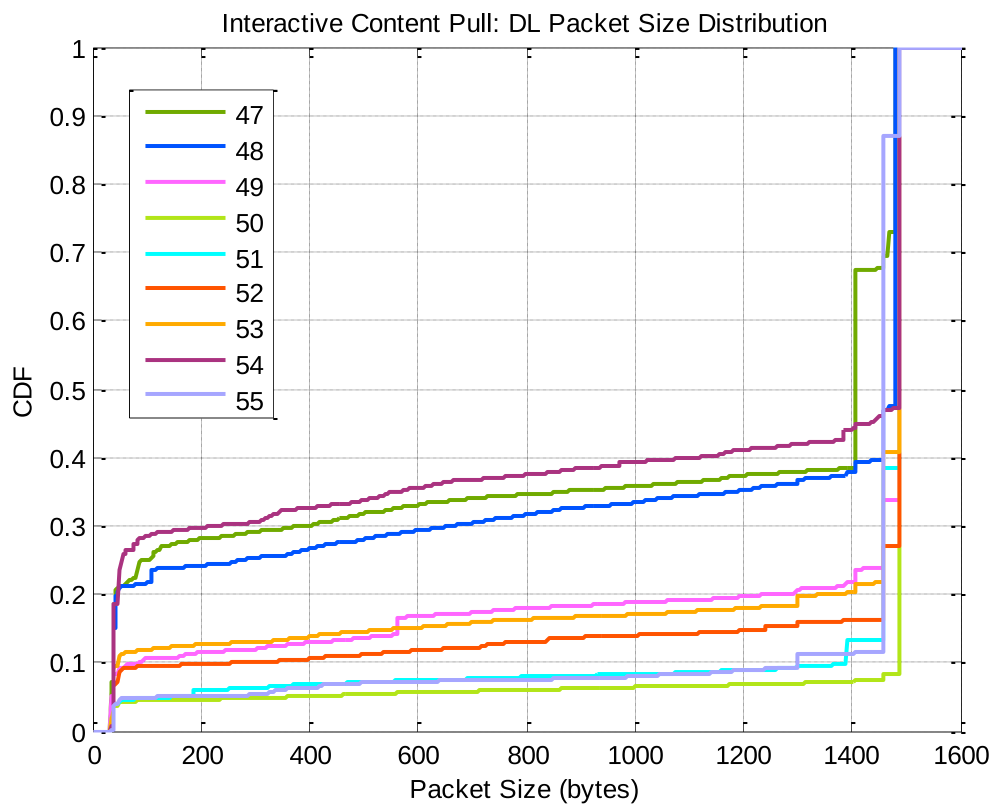

Figure 4.2.4-5: Interactive Content Pull Traffic - Packet Size CDFs (downlink)

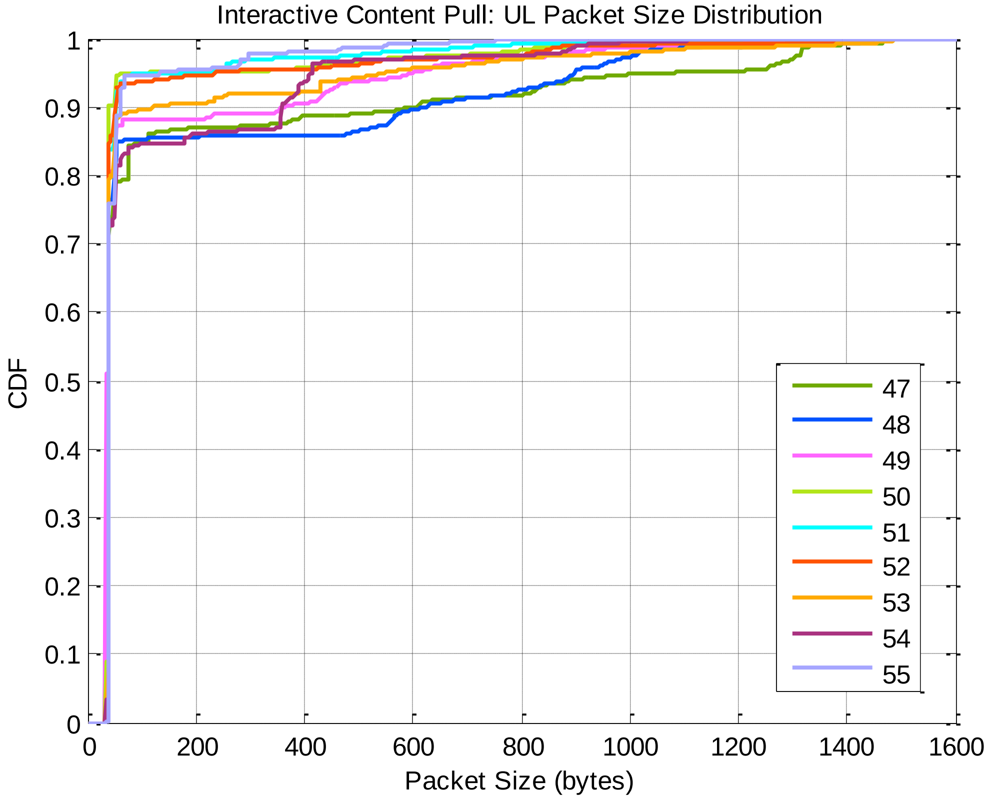

Figure 4.2.4-6: Interactive Content Pull Traffic - Packet Size CDFs (uplink)

5 Evaluation of existing EUTRAN functionality

5.1 Evaluation of uplink control resources

5.1.1 PUCCH resource allocation

The PUCCH channel is used for SR, CQI/PMI/RI reports, ACK/NACK.

In this evaluation, the amount of resources (number of Physical Resource Blocks - PRBs) occupied by PUCCH due to different kinds of usage has been derived per the following, assuming one PRB can accommodate M_{PUCCH1} =18 SR or A/N, or M_{PUCCH2} = 12 CQI reports. N_{UE} denotes the number of connected mode UEs within a cell whilst T_{DSR}, T_{CQI} and T_{SPS} denote the periodicities (in ms) of dedicated SR, CQI and SPS resources respectively.

- For D-SR: $NRB_{PUCCH}^{DSR} = \frac{N_{UE}}{M_{PUCCH1} T_{DSR}}$

- For CQI: $NRB_{PUCCH}^{CQI} = \frac{N_{UE}}{M_{PUCCH2} T_{CQI}}$

- For SPS A/N: $NRB_{PUCCH}^{SPS} = \frac{N_{UE}}{M_{PUCCH1} T_{SPS}}$

- For Dynamic Scheduling A/N: PUCCH resources for A/N are implicitly allocated by the presence and CCE location of the corresponding DL grant on PDCCH ($n^{(1)}_{PUCCH} = n_{CCE} + N^{(1)}_{PUCCH}$ [3]). A maximum of 3 OFDM symbols is assumed for L1 signalling, resulting in almost 43 CCEs for PDCCH. The maximum reserved PUCCH A/N resource will be less than 3 PRBs $\lceil 43/18 \rceil$.

- For A/N Repetition: The number of UEs which require PUCCH ACK/NACK repetition is limited, hence 1 PRB is assumed to be sufficient.

Figure 5.1.1-1 shows the allocated PRBs for the PUCCH due to different kinds of usage assuming there are $N_{UE} = 300$ connected UEs in a 10MHz bandwidth cell.

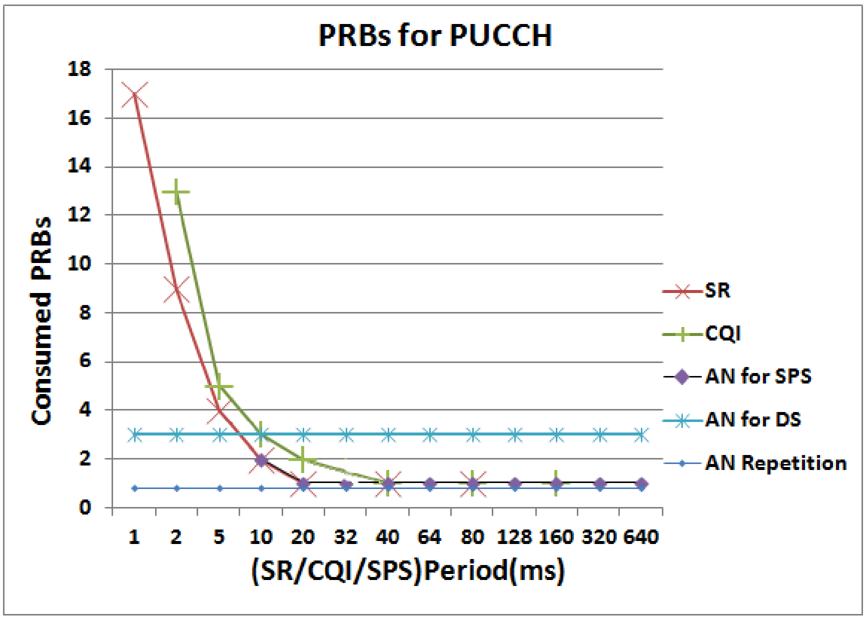

Figure 5.1.1-1: PRBs allocated for PUCCH

The number of consumed PRBs for PUCCH resources increases for short SR/CQI periods.

5.1.2 PUCCH resource usage

5.1.2.1 PUCCH resource usage for SR

A UE uses the PUCCH resources allocated for SR only when there is a scheduling request, therefore the utilisation ratio of the allocated resource depends on the traffic type. The utilisation of PUCCH SR resource has been evaluated for different data applications and different SR periods and the results are provided in table 5.1.2.1-1.

For most traffic, the usage ratio of PUCCH allocated for SR is very low.

The D-SR periodicity will also impact user experience and this aspect should be taken into account.

Table 5.1.2.1-1: PUCCH utilisation ratio for SR

Traffic Type	Mean Packet Interval(ms)	SR usage ratio			
		80ms period	10ms period	5ms period	1ms period
Background (of IM) (1)	6253	0.67%	0.08%	0.04%	0.008%
IM (1)	1905	2.46%	0.31%	0.15%	0.03%
Gaming (2)	44	---	22.7%	11.4%	2.3%
VoIP (2)	20 (160ms for SID frame, 50% activity factor is assumed)	---	31.3%	15.5%	3.1%
Video Telephony (2)	40	---	25%	12.5%	2.5%
Web Browsing (2)	2000	3.3%	0.04%	0.02%	0.004%
FTP (2)	1000	15%	1.9%	0.96%	0.19%

Note 1: Statistics of the traffic traces used for this evaluation may be found in [4]

Note 2: Source traffic based on models which are provided in [5]

Resources reserved for dedicated SR on PUCCH may be expressed as an UL Physical Resource Block (PRB) overhead. The overhead may be defined as the sum of PUCCH PRBs (for D-SR) that need to be reserved for a set of users within the cell, divided by the sum of PUSCH PRBs needed to carry their user plane data.

Figure 5.1.2.1-1 shows this ratio for an evaluation in which background traffic traces 28, 29, 30 and 31 (Annex A.1) were used and assuming that M_{PUCCH1} =18 SRs may be multiplexed within a PUCCH PRB.

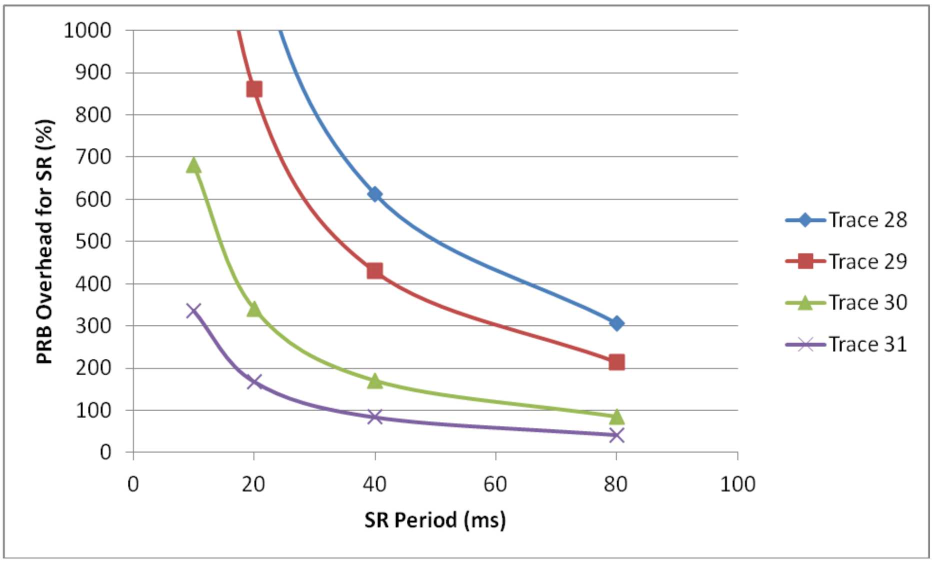

Figure 5.1.2.1-1: PRB overhead due to dedicated scheduling request on PUCCH (Background Traffic)

5.1.3 PRACH resource usage

If dedicated SR resources on PUCCH are not allocated to a connected mode UE, the UE instead uses the random access procedure to request PUSCH resources when user plane data arrives for uplink transmission. Figure 5.1.3-1 shows the amount of PRACH resources needed to accommodate these requests as a function of the number of users per cell and expressed relative to the number of PUSCH PRBs needed to carry the user plane data. The evaluation assumes a 1% preamble collision probability target and is based on background traces 28, 29, 30 and 31 (Annex A.1), In the evaluation the amount of PRACH resources is increased as the size of the user population increases, in order not to exceed the stated collision probability target. The number of PRACH PRBs per frame is derived as:

$$N_{prach}^{PRB} = 6\left(\frac{-\gamma}{64.\ln(0.99)}\right)$$

… where γ is the total offered preamble load. N_{prach}^{RB} conforms to one of the available PRACH configurations (for FDD) containing {3, 6, 12, 18, 30, 60} PRBs per frame.

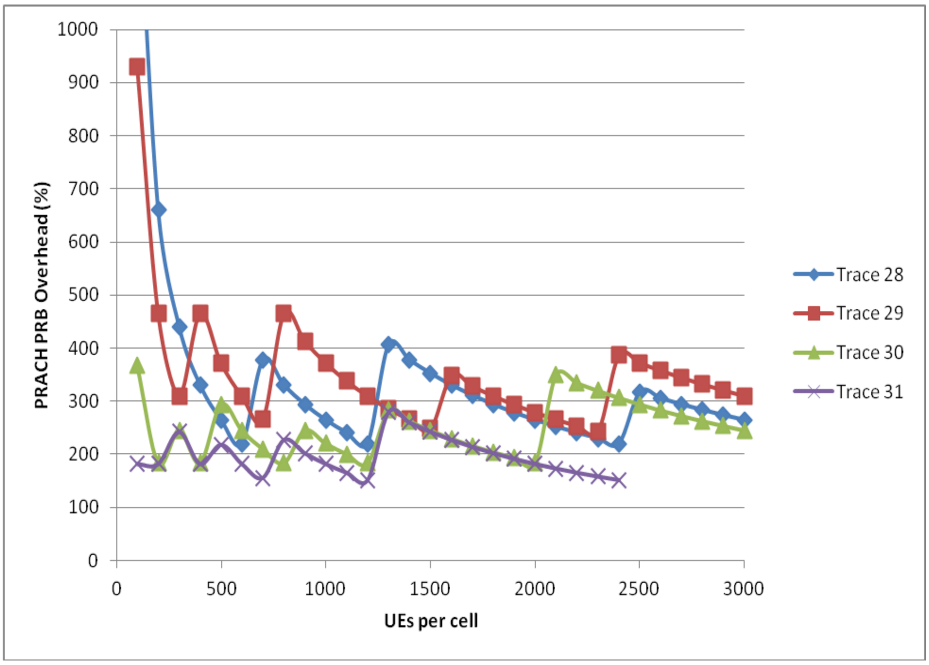

Figure 5.1.3-1: PRB overhead due to scheduling request on PRACH (Background Traffic, 1% preamble collision probability)

5.2 Evaluation of RRC State Transitions

5.2.1 Signalling Associated with RRC Connection Setup/Release

Some traffic profiles have the potential to cause frequent RRC connection setup/release cycles.

This section provides an understanding of the cost of setting up each RRC connection, which may be of relevance for background traffic where the volume of user data exchanged during each of the RRC connection durations may be small.

Two example RRC connection setup/release sequences are shown in Tables 5.2.1-1 and 5.2.1-2 . Both examples assume that all messages are received without errors (i.e. no retransmissions). At the start of the sequences, the UE is assumed to be in EMM_REGISTERED and in ECM_IDLE.

In Table 5.2.1-1, some of the associated layer 1 control aspects are also included. MAC PDU sizes are shown without padding (or padding sub-headers). CQI/CSI transmissions may also be present following the RRC Connection Setup message but are not explicitly shown in the table.

Table 5.2.1-2 shows an alternative example RRC connection setup/release sequence. The associated layer 1 signalling is not explicitly shown in this table (except for the RACH preamble).

Table 5.2.1-1 – RRC Connection Setup / Release Sequence – Example 1

Step	↑ UL ↓ DL	Contents (of MAC PDU or L1 control)	MAC PDU Size (Bytes)	
			UL	DL
1	↑	Preamble	--	--
2	↓	Random Access Response (+PDCCH DL grant)	--	8
3	↑	RRC Connection Request	7	--
4	↓	PHICH ACK	--	--
5	↓	Contention Resolution CE (+PDCCH DL grant)	--	7
6	↑	PUCCH ACK	--	--

7	↓	RRC Connection Setup (+PDCCH DL grant)	--	30
8	↑	PUCCH ACK	--	--
9	↑	Scheduling Request	--	--
10	↓	PDCCH UL grant	--	--
11	↑	RRC Connection Setup Complete (inc. NAS Service Request) + PHR + short BSR	20	--
12	↓	PHICH ACK	--	--
13	↓	RLC Status PDU (+PDCCH DL grant)	--	3
14	↑	PUCCH ACK	--	--
15	↓	Security Mode Command (+PDCCH DL grant)	--	11
16	↑	PUCCH ACK	--	--
17	↑	Scheduling Request	--	--
18	↓	PDCCH UL grant	--	--
19	↑	Security Mode Complete + RLC Status PDU + PHR + short BSR	17	--
20	↓	PHICH ACK	--	--
21	↓	RLC Status PDU (+PDCCH DL grant)	--	3
22	↑	PUCCH ACK	--	--
23	↓	RRC Connection Reconfiguration (+PDCCH DL grant)	--	45
24	↑	PUCCH ACK	--	--
25	↑	Scheduling Request	--	--
26	↓	PDCCH UL grant	--	--
27	↑	RRC Connection Reconfiguration Complete + RLC Status PDU + PHR + short BSR	19	--
28	↓	PHICH ACK	--	--
29	↓	RLC Status PDU (+PDCCH DL grant)	--	3
30	↑	PUCCH ACK	--	--
31	↓	RRC Connection Release (+PDCCH DL grant)	--	10
32	↑	PUCCH ACK	--	--
33	↑	Scheduling Request	--	--
34	↓	PDCCH UL grant	--	--
35	↑	RLC Status PDU	3	--
36	↓	PHICH ACK	--	--
Total Bytes			**66**	**120**
Number of occupied subframes			**18**	**18**

Table 5.2.1-2 – RRC Connection Setup / Release Sequence – Example 2

Step	**↑ UL ↓ DL**	**Contents (of MAC PDU)**	**MAC PDU Size (Bytes)**	
			UL	**DL**
1	↑	Preamble	--	--
2	↓	Random Access Response	--	7
3	↑	RRC Connection Request	7	--
4	↓	RRC Connection Setup + UE *Contention Resolution Identity* MAC CE)	--	38
5	↑	Buffer Status Report	2	--
6	↑	RRC Connection Setup Complete (+ NAS Service Request)	20	--
7	↓	RLC Status Report	--	3
8	↓	Security Mode Command	--	11
9	↓	RRC Connection Reconfiguration (+NAS: Activate Dedicated EPS Bearer Context Req)	--	118
10	↑	Buffer Status Report	2	--
11	↑	Security Mode Complete	13	--
12	↑	RRC Connection Reconfiguration Complete	10	--

13	↓	RLC Status Report	--	3
14	↓	Buffer Status Report	2	--
15	↑	ULInformationTransfer (NAS: Activate Dedicated EPS BEARER Context Accept)	13	--
16	↓	RLC Status Report	--	3
17	↓	RRC Connection Release	--	10
18	↑	RLC Status Report	3	--
Total Bytes			**72**	**193**

5.2.2 Signalling Load

RRC state control may be based on inactivity timers within the eNB. Following the detection of data inactivity for a period of time, the eNB may choose to direct the UE to idle mode via the sending of an RRC Connection Release. The presence of user plane traffic will trigger a subsequent return to connected mode via an RRC Connection Setup procedure (such as those shown in section 5.2.1).

Some traffic types (e.g. background and IM) comprise regular or sporadic short data exchanges that may be relatively widely interspersed in time. In this case, one of two outcomes is likely to result depending upon the network's configuration of the RRC inactivity timer:

A) For shorter timer values, the frequency of RRC state transitions becomes high: as a result, Uu and S1 signalling overheads are increased

B) For longer timer values, Idle mode is seldom used: The background activity retains the device in an RRC connected mode state

This section provides analyses concerning how RRC inactivity timer values affect RRC connection frequency (and hence signalling load) and the proportion of time the UE would spend in connected mode as a result.

5.2.2.1 Results for Background Traffic

Figure 5.2.2.1-1 shows the number of complete RRC connection setup/release cycles per minute that would result in the presence of background traffic as a function of varying an RRC inactivity-timer within the eNB. The results are for the case of zero or low mobility. Numerical legend labels correspond to the traffic scenario Trace IDs listed in Annex A.1. Alphabetical legend labels correspond to traces from other sources as listed in Annex A.2.

Figure 5.2.2.1-2 shows the corresponding percentage of time that the UE would spend in the connected mode.

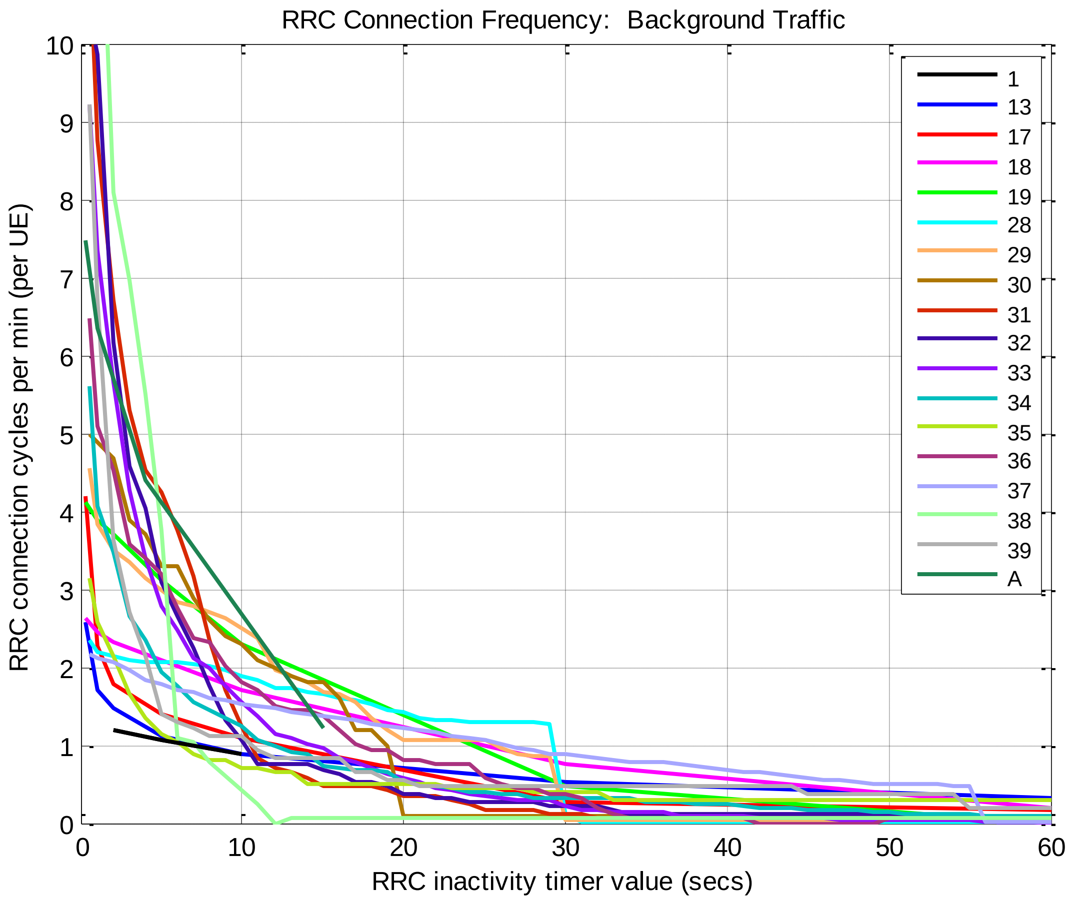

Figure 5.2.2.1-1: RRC Connection Frequency vs. RRC inactivity timer value (Background Traffic)

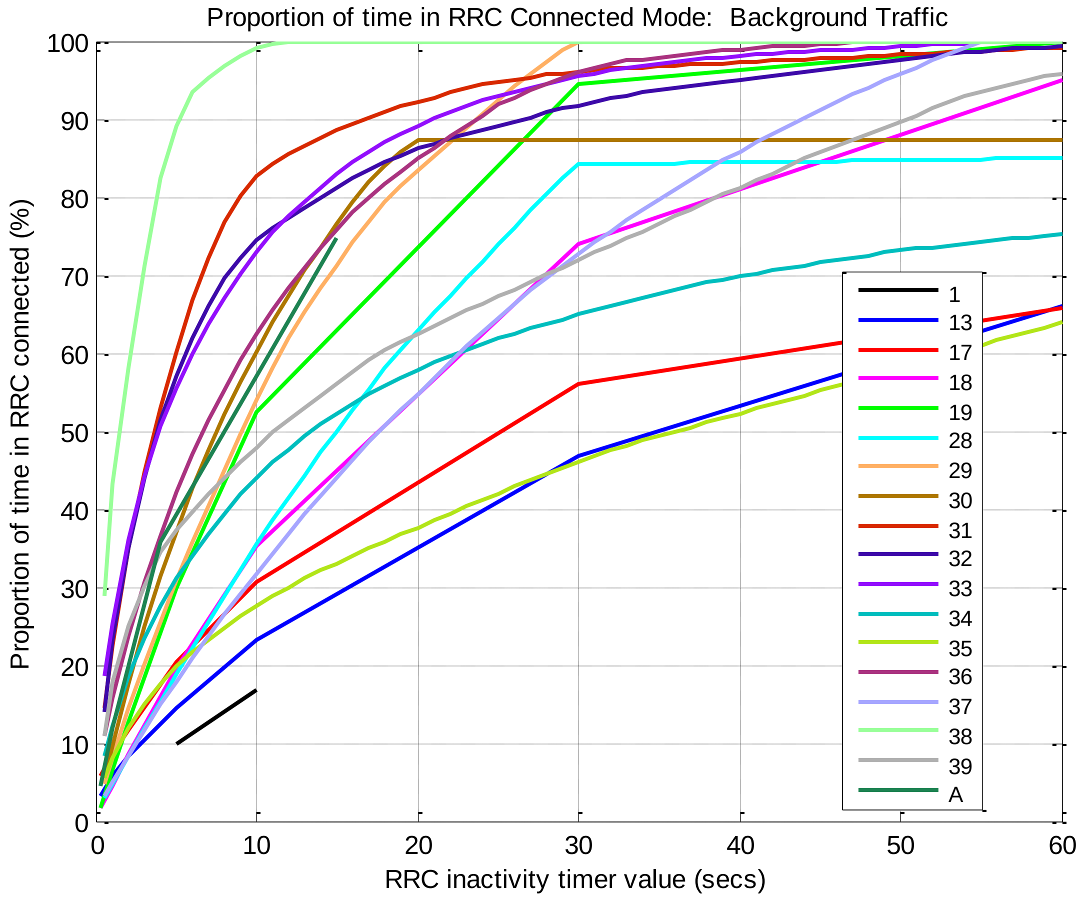

Figure 5.2.2.1-2: Time in Connected Mode vs. RRC inactivity timer value (Background Traffic)

5.2.2.2 Results for IM Traffic

Figure 5.2.2.2-1 shows the number of complete RRC connection setup/release cycles per minute that would result in the presence of IM traffic as a function of varying an RRC inactivity-timer within the eNB. The results are for the case of zero or low mobility. Numerical legend labels correspond to the traffic scenario Trace IDs listed in Annex A.1. Alphabetical legend labels correspond to traces from other sources as listed in Annex A.2.

Figure 5.2.2.2-2 shows the corresponding percentage of time that the UE would spend in the connected mode.

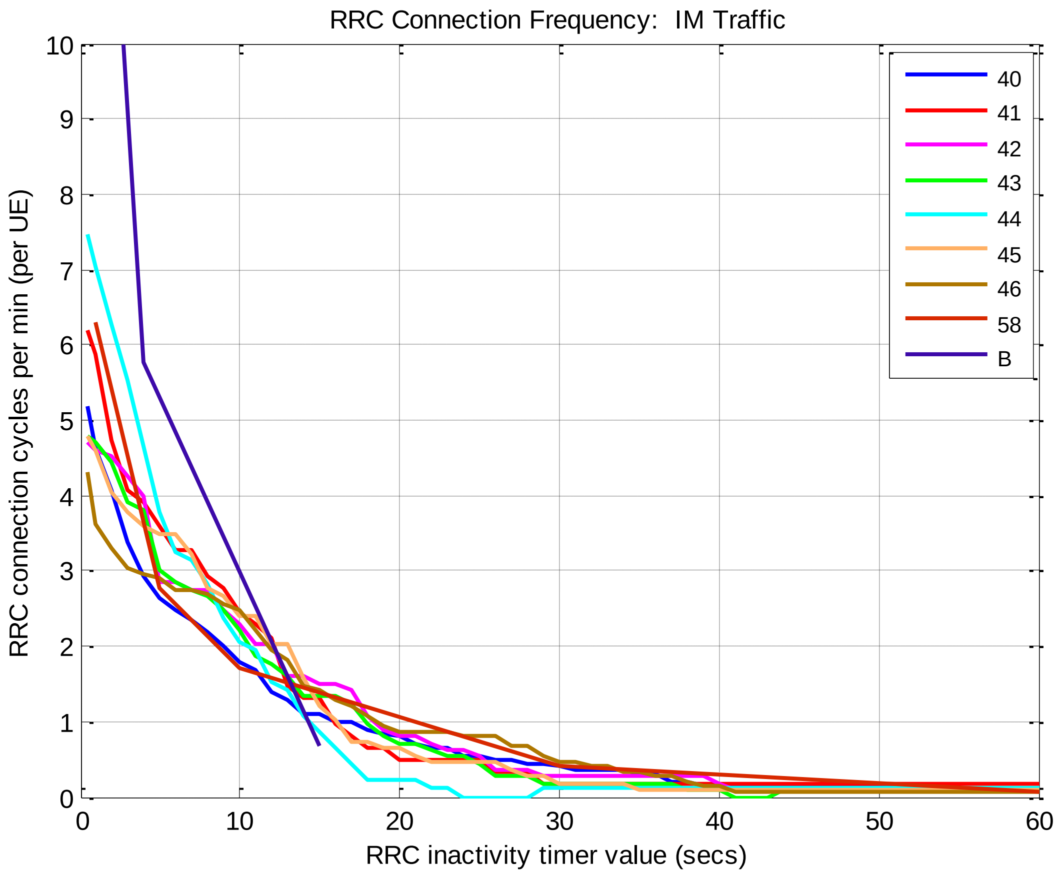

Figure 5.2.2.2-1: RRC Connection Frequency vs. RRC inactivity timer value (IM Traffic)

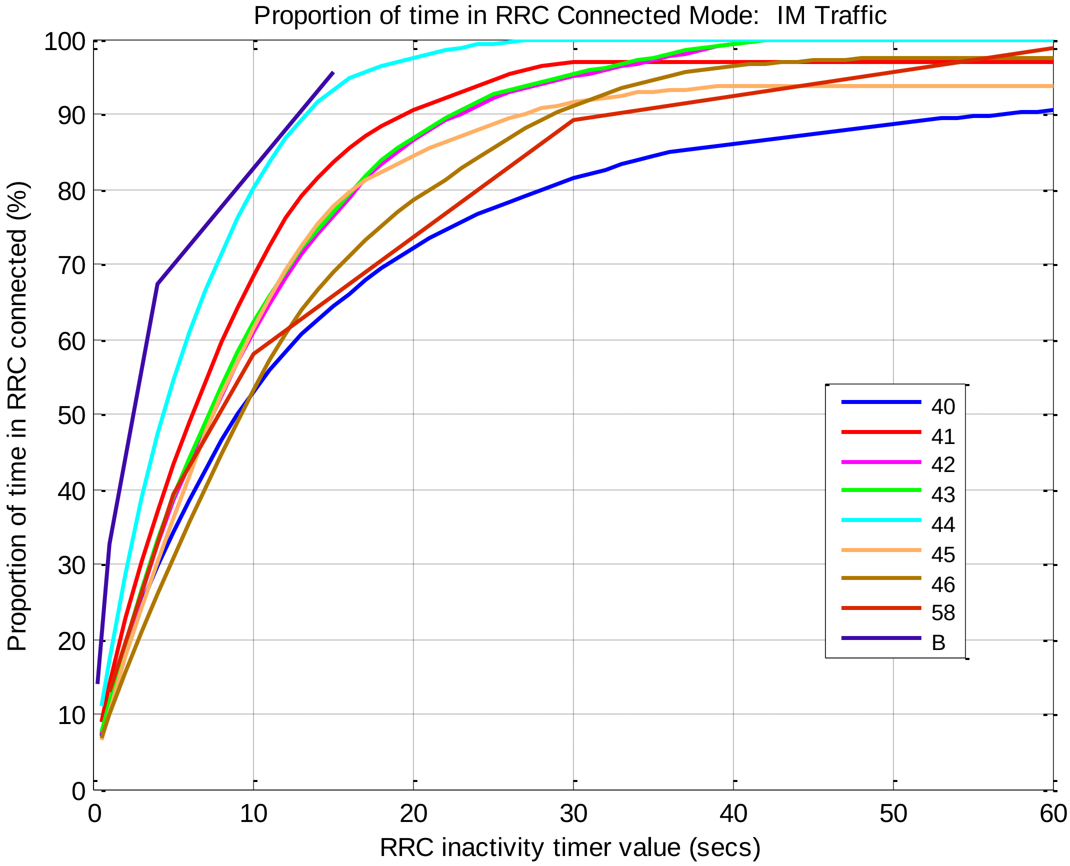

Figure 5.2.2.2-2: Time in Connected Mode vs. RRC inactivity timer value (IM Traffic)

5.3 Evaluation of Mobility Related Signaling

5.3.1 Signalling Associated with Handover

While the UE remains in RRC Connected state, mobility from one cell to another cell involves a Handover procedure. Handover involves signaling on both the Uu and backhaul (X2/S1) interfaces, and an example of the signaling on the Uu interface is given in Figure 5.3.1-1.

Table 5.3.1-1, shows the number of bytes of signalling data corresponding to the Uu signalling messages shown in Figure 5.3.1-1. This assumes that all messages are received without errors (i.e. no retransmissions). MAC PDU sizes are shown without padding (or padding sub-headers). CQI/CSI transmissions may also be present but are not explicitly shown in the table.

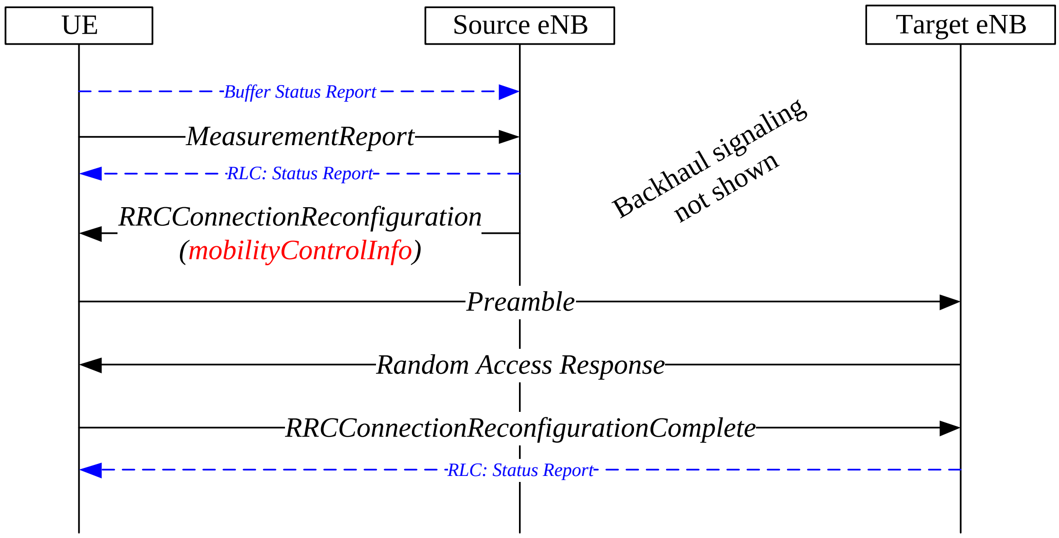

Figure 5.3.1-1: Signaling Flow Associated with Handover

Table 5.3.1-1 – RRC Signalling for (intra-system) Handover procedure – Example

Step	↑ UL ↓ DL	Contents (of MAC PDU)	MAC PDU Size (Bytes)	
			UL	DL
1	↑	Buffer Status Report	2	--
2	↑	Measurement Report	19	--
3	↓	RLC Status Report	--	3
4	↓	RRC Connection Reconfiguration including mobilityControlInfo.	--	87
5	↑	Preamble	--	--
6	↓	Random Access Response	--	7
7	↑	RRC Connection Reconfiguration Complete	13	--
8	↓	RLC Status Report	--	3
Total Bytes			34	100

5.3.2 Selecting RRC State for a mobile UE

The cost of mobility in RRC Connected state is higher than the cost of mobility in RRC Idle State. While the cost of RRC Connected mobility is given in Section 5.3.1, RRC Idle State mobility in most cases does not involve any air interface or backhaul signaling. The exception is when a UE in RRC Idle State moves outside the network provided list of tracking areas and needs to perform a Tracking Area Update procedure. In this section (Section 5.3), it is assumed that the UE does not move outside the list of assigned tracking areas.

Due to the fact that in the current LTE system, UE-controlled mobility applies only in idle mode, then from the point of view of mobility signaling alone, it is desirable to place the UE in RRC Idle State as much as possible. However, as noted in Section 5.2, frequent transitions between RRC Idle and Connected states are also undesirable. Some example schemes that are possible within the existing LTE system for controlling the RRC state of a UE are listed below. Each scheme obtains a different tradeoff between frequency of RRC state transitions and the frequency of mobility signaling. However, it is also the case that each scheme achieves a different trade off between the time spent in the connected and idle modes and hence impacts to UE battery consumption, the number of simultaneous RRC connections within a cell/eNB and the usage of system resources are also of importance and need to be taken into consideration.

1. **Full use of RRC Connected State:** In this scheme, the UE never transitions to RRC Idle State.

2. **Network Initiated RRC Release (based on RRC Inactivity Timer in the Network):** As mentioned in Section 5.2, the eNB can release the RRC connection when there is no data activity for a period exceeding an RRC inactivity timer.

3. **Network Initiated RRC Release based on mobility:** In this scheme, the eNB releases a UE's RRC connection only if both of the following criteria are met: i) there has been no data activity for the UE for the past N seconds, and ii) a need for handover for the UE has been identified (e.g. the eNB has received a measurement report with A3 event). Thus, the eNB performs RRC connection release instead of performing handover. If a handover is required within N seconds of previous user-plane activity, the handover is performed and the RRC connection is not released..

5.3.3 Evaluation of schemes to select a RRC State for a mobile UE

By using a traffic trace and a model for UE mobility, it is possible to compute the number of RRC State Transitions and the number of HO events. The UE mobility model may either be abstract (e.g. a random variable to model the time between handovers), or may be based on UE mobility simulations in a multicell simulation layout.

The number of RRC Connection Setup events, the number of HO events and the time in connected mode with a varying mobility rate are shown below in tables 5.3.3-1, 5.3.3-2 and 5.3.3-3 for Trace ID-1 (of Annex A.1).

Table 5.3.3-1: RRC Connection Setups per Hour per UE (Trace ID-1)

Scheme	Mobility Rate (cell changes per minute per UE)				
	0.1	0.3	1	3	10
1. Full C-DRX	0				
2a. NW Initiated RRC Release (timer 5s)	64				
2b. NW Initiated RRC Release (timer 10s)	53				
3a. NW Initiated RRC Release based on mobility (timer 5s)	5.2	12	26	40	52.2
3b. NW Initiated RRC Release based on mobility (timer 10s)	4.1	12.1	22.7	34.3	45.6

Table 5.3.3-2: Handover Events per Hour per UE (Trace ID-1)

Scheme	Mobility Rate (cell changes per minute per UE)				
	0.1	0.3	1	3	10
1. Full C-DRX	6	18	60	180	600
2a. NW Initiated RRC Release (timer 5s)	0.6	1.8	6.1	18.5	62
2b. NW Initiated RRC Release (timer 10s)	1.0	3.3	10.9	32.3	109
3a. NW Initiated RRC Release based on mobility (timer 5s)	0.5	1.0	5.4	18.0	63
3b. NW Initiated RRC Release based on mobility (timer 10s)	1.1	3.7	10.3	33.0	111

Table 5.3.3-3: Fraction of Time in Connected Mode (Trace ID-1)

Scheme	Mobility Rate (cell changes per minute per UE)				
	0.1	0.3	1	3	10
1. Full C-DRX	1				
2a. NW Initiated RRC Release (timer 5s)	0.10				
2b. NW Initiated RRC Release (timer 10s)	0.18				
3a. NW Initiated RRC Release based on mobility (timer 5s)	0.91	0.77	0.53	0.32	0.19
3b. NW Initiated RRC Release based on mobility (timer 10s)	0.93	0.81	0.56	0.38	0.26

The figure 5.3.3-1 shows the comparison of signalling load to data bytes per hour across the different schemes in tables 5.3.3-1, 5.3.3-2. The mean data rate value is obtained from table A.1-1 in Appendix A.1.

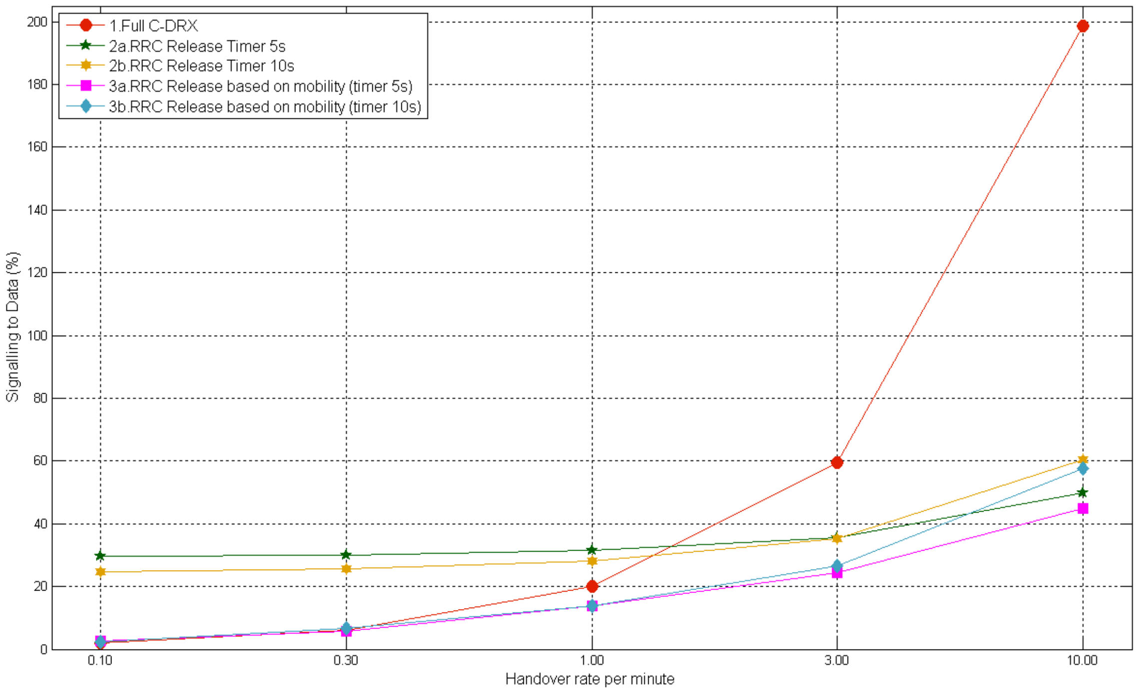

Figure 5.3.3-1: Signalling load to data bytes for background trace ID-1

A further set of evaluations for trace ID-17 of the Annex A.1 is shown here.

The cut-off UE mobility rate above which it is better to move the UE to RRC idle state when there is no packet activity and below which it is acceptable to maintain in RRC Connected state (Always on/ Full C-DRX) is shown in tables 5.3.3-4 and 5.3.3-5. The tables captured for the background trace ID-17 (of Annex A.1) depict the signalling load while performing RRC state transitions and handovers. The trace spans a duration of 24 hours, with data analysed over a wide range of RRC Inactivity values (including a Full Connected case) and handover rates.

Table 5.3.3-4: Number of Handovers and RRC state transitions for background trace ID-17

RRC Inactivity Timer (s)	Number of HOs per hour (per UE)								Number RRC Connected to Idle Transitions per hour (per UE)
	HO rate per minute								
	0.10	0.30	0.50	0.75	1.00	2.00	4.00	10.00	
1	3.1	3.1	8.0	5.9	14.6	20.5	24.3	39.5	124.4
5	3.5	5.2	9.7	11.1	18.7	29.8	41.9	99.5	87.3
10	3.8	6.2	11.4	14.6	22.9	41.9	70.0	173.3	69.3
30	4.5	9.7	17.0	25.3	35.0	69.0	133.8	330.7	19.8
60	4.5	10.7	20.8	30.2	41.2	80.4	159.1	396.5	10.4
Infinity	5.9	17.7	29.8	44.7	60.0	119.9	239.9	600.0	0.0

Table 5.3.3-5: Total Signalling load in bytes due to Handovers and RRC state transitions for background trace ID-17

RRC Inactivity Timer (s)	Total Signalling Load Bytes due to HO and RRC state transitions per hour (per UE)							
	HO rate per minute							
	0.10	0.30	0.50	0.75	1.00	2.00	4.00	10.00
1	23562.0	23562.0	24212.2	23933.6	25094.7	25884.3	26395.2	28438.8
5	16710.5	16942.7	17546.5	17732.3	18754.1	20240.3	21865.9	29576.0
10	13404.9	13730.0	14426.7	14844.7	15959.4	18513.9	22276.0	36117.0
30	4278.5	4975.2	5950.5	7065.2	8365.7	12917.4	21602.7	47983.7
60	2537.9	3373.9	4720.8	5974.9	7461.1	12709.1	23252.1	55068.1
Infinity	789.6	2368.7	3994.3	5991.5	8035.1	16070.0	32140.0	80397.0

Note: For the above calculations, the number of bytes per RRC connection is taken from Table 5.2.1-1 and number of bytes per Handover message are taken from Table 5.3.1-1.

The figure 5.3.3-2 shows the different signalling load to data bytes per hour percentage data sets for different mobility rates and various RRC inactivity timers providing a visual representation of the data corresponding to table 5.3.3-5. The mean data rate value is obtained from table A.1-1 in Appendix A.1.

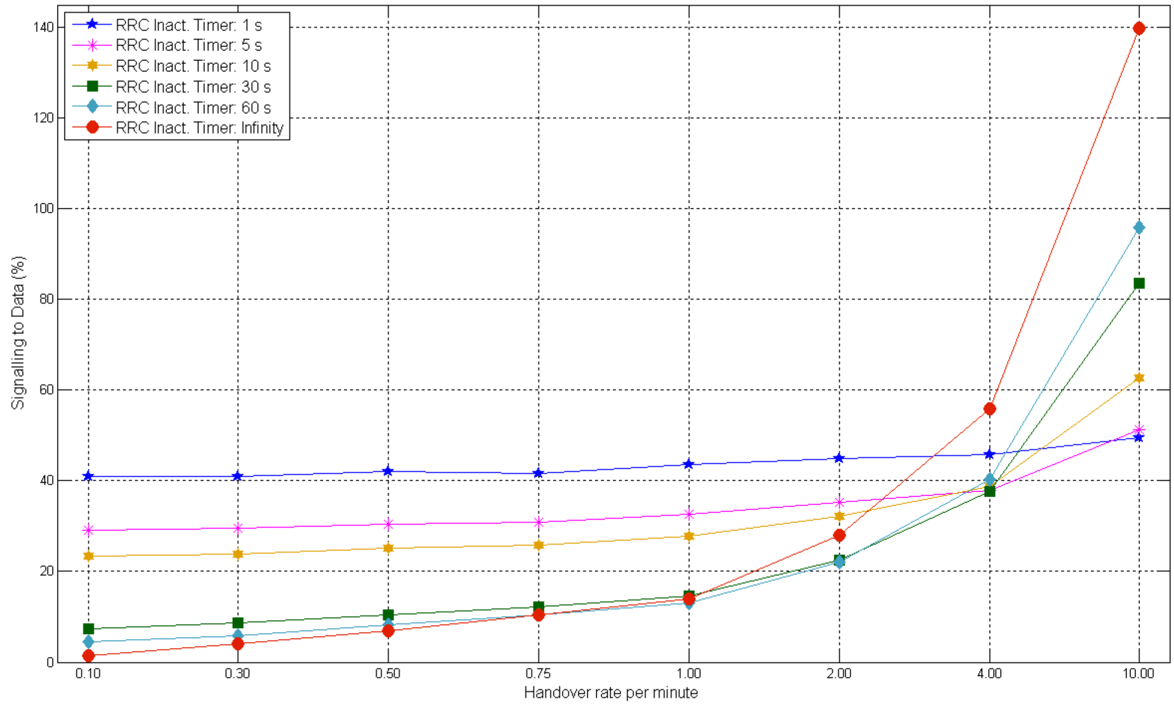

Figure 5.3.3-2: Signalling load to data bytes for background trace ID-17

From the above results, the following observations can be made about balancing mobility and RRC state transition signalling, in the context of background applications.

1. Full use of RRC Connected State, i.e. not having any transitions to RRC Idle mode can eliminate the RRC Connection Setup and Release signalling, with mobility signalling events then increasing correspondingly with the mobility of the UE.

2. Use of Network Initiated RRC Release based on fixed RRC Inactivity Timer can result in a high number of RRC Connection Setup (and Release) events, while maintaining a number of mobility events that is dependent on the length of the timer. In this case, the optimum RRC Inactivity Timer to minimize the signaling load is a function of the UE mobility rate and the traffic characteristics (e.g. packet inter arrival time).

3. Use of Network Initiated RRC Release based on mobility, at low mobility rates, exhibits handover and RRC connection setup frequencies similar to Full Connected DRX, while at high mobility rates the frequency of RRC connection setups and handovers are similar to Network Initiated RRC Release.

5.4 Evaluation of UE power consumption

5.4.1 Power consumption as a function of DRX long cycle length

In this section, an evaluation of UE power consumption is shown for background traffic with varying burst inter-arrival times and for different RRC inactivity release timers and DRX configurations. Mobility is considered with UEs moving at 3kmph and 30kmph in random fashion.

The following DRX settings are used in the evaluations shown below in Figures 5.4.1-1 to 5.4.1-4.

Feature/Parameter	Configuration	Value/Description
DRX	Long cycle length Short cycle length Short cycle duration Inactivity timer On duration timer	80, 160, 320, 640, 1280, 2560 ms 40 ms ½ long cycle length (max 640 ms) 10 ms 5 ms

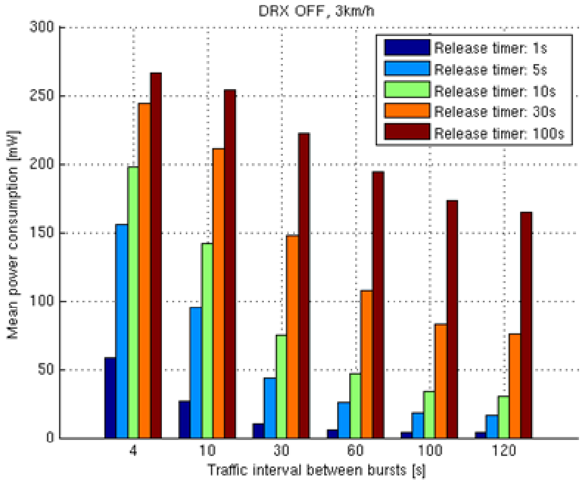

Figure 5.4.1-1 UE power consumption, DRX "off", 3kmph

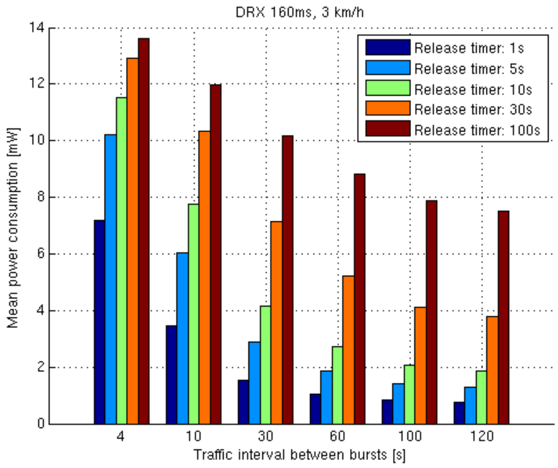

Figure 5.4.1-2 UE power consumption, DRX long cycle duration 160ms, 3kmph

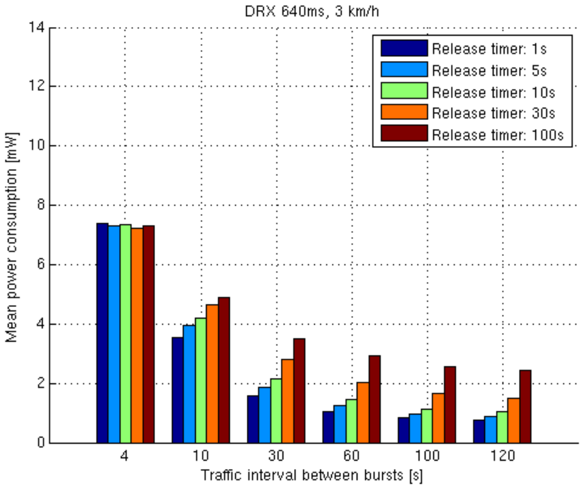

Figure 5.4.1-3 UE power consumption, DRX long cycle duration 640ms, 3kmph

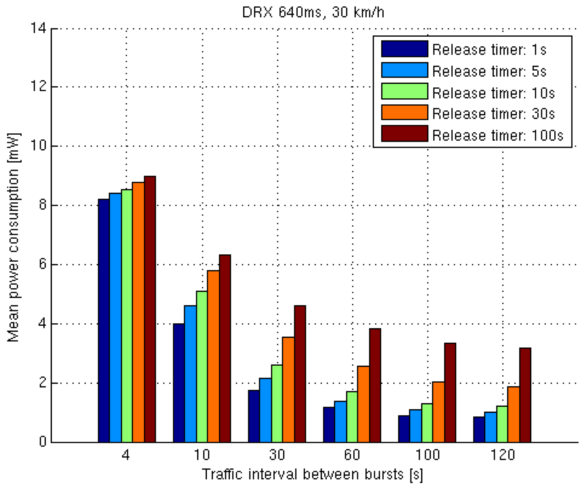

Figure 5.4.1-4 UE power consumption, DRX long cycle duration 640ms, 30kmph

Note: Traffic profile C from Annex A.2 was used as the basis for the above evaluations. The above figure is taken from R2-120367.

Another metric for UE power consumption is the battery duration. The impact of various DRX long cycle periods in connected mode on UE battery duration is shown in Figure 5.4.1-5 below, where the relative average battery duration (normalised to the battery duration at 3 kmph with no DRX) is shown at various velocities and for different DRX long cycle durations.

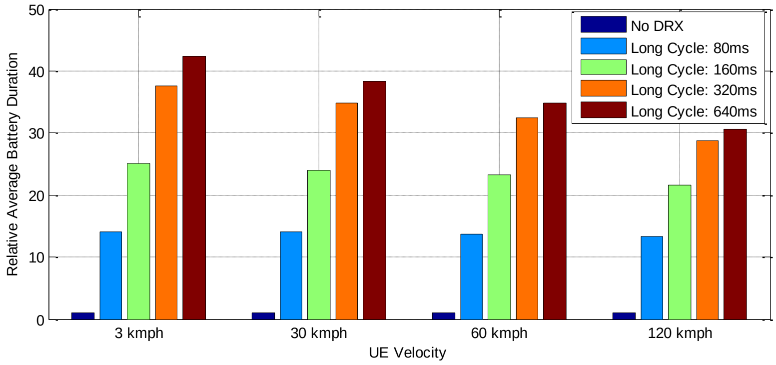

Figure 5.4.1-5: UE relative battery duration as a function of DRX period length

Note: Traffic profile D from Annex A.2 was used as the basis for the above evaluations. The above figure is taken from R2-120578.

The following observations can be made from the above results:

- The RRC release timer value has a large impact on the relative power consumption, especially with shorter DRX long cycles
- Terminal speed does not have a strong influence on the power consumption

The evaluations above consider the case of the UE moving to idle mode at the expiry of the network idle inactivity timer. Conversely the evaluations of Figure 5.4.1-6 below consider the power consumption of a UE which is held in RRC connected mode for most of the time (with a relatively large RRC release timer – 100 s). Different DRX configurations are used to study the impact of DRX on the UE power consumption in connected mode.

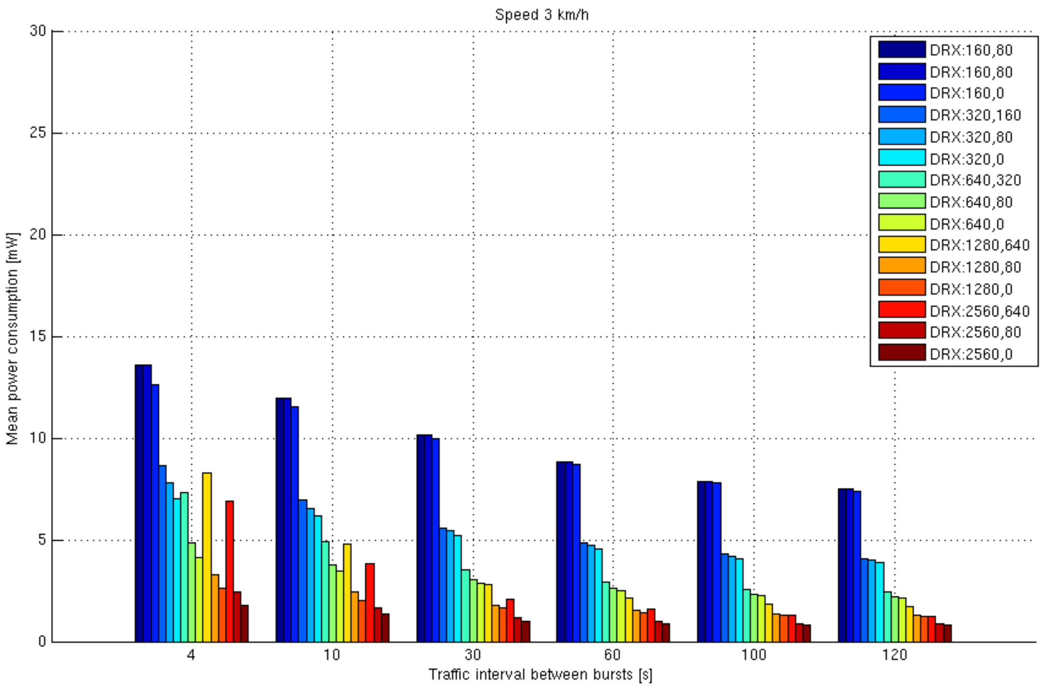

Figure 5.4.1-6: Mean UE power consumption with different DRX configurations (legend: "DRX: long cycle, short cycle timer")

Note: Traffic profile C from Annex A.2 was used as the basis for the above evaluations. The above figure is taken from R2-120500.

The following observations can be made from the above results:

- Longer Long DRX cycles give lower power consumption in RRC connected mode

In case of traffic with shorter inter arrival times (4-10 secs), a significant increase of power consumption in RRC connected mode can be observed for the DRX configurations comprising a longer short cycle timer. This is more noticeable in case of the configurations with longer long DRX cycles (640 … 2560 ms).

The above evaluations show that the power consumption of a connected mode UE is dependent upon the DRX configuration. Specifically, the use of longer DRX cycles helps to reduce power consumption for long RRC release timers.

In the evaluations shown in Figures 5.4.1-7 and 5.4.1-8, the power consumption of a connected mode UE (infinite RRC release timer) is compared with that of a UE that spends more of its time in idle (short RRC release timer of 1 sec) and which transitions to connected mode when sending data. Other simulation parameters are shown in the table below.

Feature/Parameter	Configuration	Value/Description
Traffic	Background traffic model	Geometric distribution of packet inter-arrival times (mean of 5s and 30s) – see traffic profile C of Annex A.2
DRX	Long cycle length Short cycle length Short cycle duration Inactivity timer On duration timer	160, 640, 1280, 2560 ms 40 ms 160 ms 10 ms 10 ms
Idle mode configuration	Paging cycle Measurement duration per cycle	1280ms 5ms

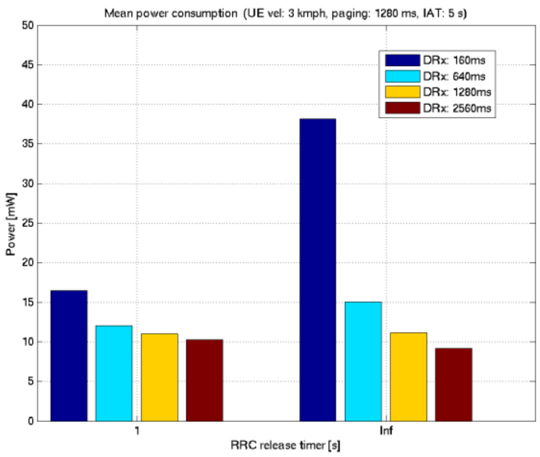

Figure 5.4.1-7: Mean UE power consumption with average traffic inter arrival time = 5 sec

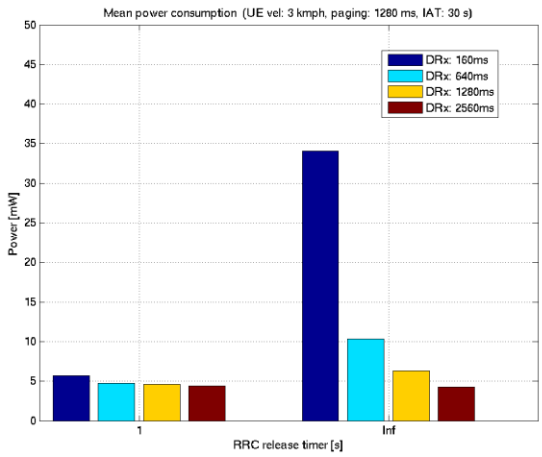

Figure 5.4.1-8: Mean UE power consumption with average traffic inter arrival time = 30 sec

Based on the above results, the following observation can be made:

- For background traffic, the power consumption of a connected mode UE can be comparable to that of a UE with a short release timer if the DRX cycle length is similar to the idle mode paging cycle.

The network may wish to also consider other factors when deciding whether to release the UE to idle or to keep it RRC connected (e.g. DRX preferences, UE mobility, UE traffic pattern, network load, number of supportable connections, signalling/resource overheads etc…).

5.4.2 Trade-off between power consumption and latency

Increasing the overall proportion of sub-frames on which the UE may sleep naturally results in a reduction in active time thus reducing the UE's power consumption. However, this comes with an increased risk of longer wake-up delays (i.e. the latency). An example of this trade-off between average UE power consumption and latency can be seen in Figure 5.4.2-1 for background traffic (Trace 29, see Annex A.1) and in Figure 5.4.2-2 for interactive content pull traffic (Trace 50, see Annex A.1). Power consumption is expressed in terms of an "Average Relative Power Metric" (ARPM) ranging from 0 to 1. This is defined as the average power consumption of the UE relative to the case of continuous transmission and reception (assuming here an FDD UE).

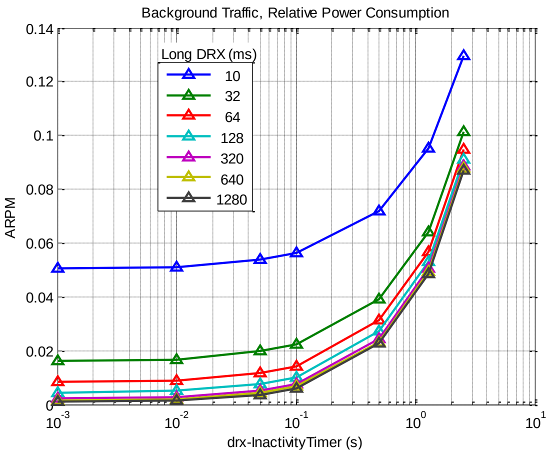

Figure 5.4.2-1a: UE power consumption as a function of Long DRX cycle period and DRX inactivity timer (background traffic)

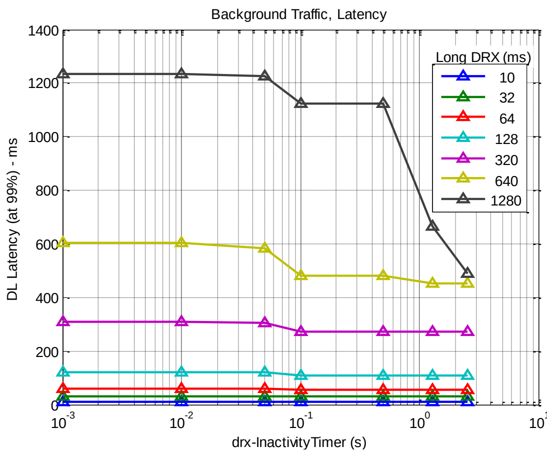

Figure 5.4.2-1b: DL latency as a function of Long DRX cycle period and DRX inactivity timer (background traffic)

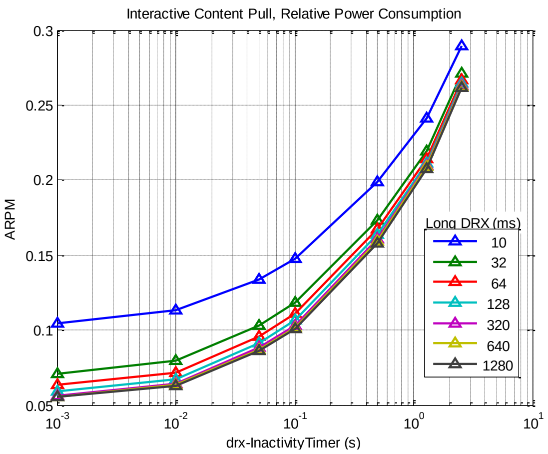

Figure 5.4.2-2a: UE power consumption as a function of Long DRX cycle period and DRX inactivity timer (interactive content pull traffic)

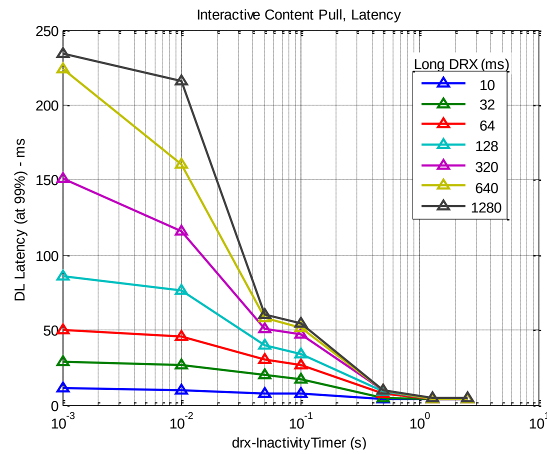

Figure 5.4.2-2b: DL Latency as a function of Long DRX cycle period and DRX inactivity timer (interactive content pull traffic)

Note: The above figures are taken from R2-120544.

Latency is likely to be a less-important consideration for background traffic and hence a DRX configuration that prioritises UE battery performance may be preferred. As shown in Figure 5.4.2-1, this may be achieved through the use of shorter DRX inactivity timers and longer DRX cycle lengths.

However, for interactive content pull traffic, latency is significantly impacted by the application of such DRX parameters. As shown in Figure 5.4.2-2b, these impacts may be largely avoided by increasing the inactivity timer to around 500ms, although application of such a latency-sensitive DRX configuration to the background traffic case could then lead to a several-fold increase in UE power consumption when compared with shorter DRX inactivity timers (Figure 5.4.2-1a).

The following observations can be made:

- DRX configurations optimised primarily for UE power consumption in background traffic scenarios may differ substantially when compared to those optimised primarily for latency such as in the case of interactive or latency-sensitive traffic.

- Application of a DRX configuration optimised primarily for latency (e.g. for interactive content pull traffic) can significantly increase UE power consumption during times of background traffic whilst the DRX configurations optimised primarily for power consumption of background traffic may cause an increase in latency for the latency sensitive traffic.

5.4.3 Trade-off between power consumption and handover performance

The use of longer DRX cycles has some potential to impact handover performance and this is evaluated in this section. This impact may be due to reduced frequency of L1 measurements or increased latency of signalling messages.

The results of Figure 5.4.3-1 below show the percentage of radio link failures per successful handover.

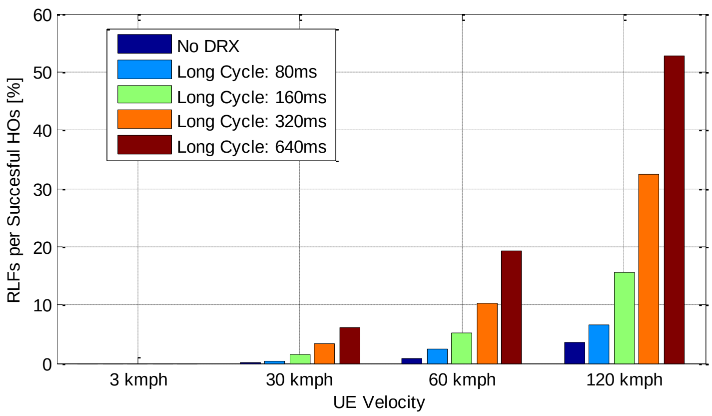

Figure 5.4.3-1: UE handover performance as a function of mobility and DRX cycle length

Note: The above figures are taken from R2-120578.

The following observations can be made from the above figure:

- Rate of radio link failure increases with longer DRX cycles
- For high mobility cases, it is preferable to keep the UE either in RRC idle state or in RRC connected state with a short DRX cycle length

6 New functionality

6.1 UE Assistance Information

In order to optimise the user experience and (for instance) to assist the eNB in configuring connected mode parameters and connection release handling, the UE may be configured to send assistance information to the eNB comprising:

- UE preference for power optimised configuration (1 bit):
  - When this indication is sent, this bit is set in accordance with the UE's preference for a configuration that is primarily optimised for power saving (e.g. a long value for the long DRX cycle or RRC connection release) or not
  - The details regarding how the UE sets the indicator are left to UE implementation
  - Mechanisms to avoid excessive signalling of this information should be provided
- UE mobility information:
  - The possibility for the UE to provide mobility information to the network during transition from IDLE to RRC connected state should be provided
  - The details of the UE mobility information are left FFS

The network response to the UE assistance information is left to network implementation.

7 Conclusions

It has been agreed to incorporate a mechanism to indicate UE preference for power optimised configuration as described in section 6.1 in Rel-11.

Annex A: Trace Information

A.1 Traffic Scenario CDF Traces

Table A.1-1: Traffic Scenario CDFs - Trace Listing

Trace -ID	Source Company	Description	Mean Rate (Bytes/s)		Mean IP Packets Per Second	
			DL	UL	DL	UL
1	Qualcomm	Background (IM QQ + Google services)	[6.58]	[4.66]	[0.0380]	[0.0427]
2	Qualcomm	Gaming (modern combat): A 3D First Person Shooter (FPS) online game	[2084.63]	[542.50]	[25.7619]	[19.9556]
3	Qualcomm	Gaming (project INF): A 2D shooting online game	[1433.00]	[185.29]	[12.7250]	[4.9979]
4	Qualcomm	Gaming (reckless racing): A car racing online game	[1517.88]	[792.65]	[4.0516]	[4.0876]
5	AT4 Wireless	Gaming (open arena): A First Person Shooter (FPS) online game.	4050.0	3909.1	25.0	90.91
6	AT4 Wireless	Gaming (dirt2): An online action game where several players race against each other in a virtual environment	640.45	658.54	11.24	12.19
7	AT4 Wireless	Gaming (team fortress 2): Another First Person Shooter (FPS) online game.	5320.0	2383.35	20.00	29.41
8	Huawei	Background (MSN)	[23.02]	[12.32]	[0.1236]	[0.1850]
9	Huawei	Background (QQ)	[48.65]	[58.33]	[0.2550]	[0.2886]
10	Huawei	Background (skype)	[6.69]	[5.33]	[0.0546]	[0.0711]
11	Huawei	IM (MSN)	[451.90]	[31.22]	[0.9538]	[0.7338]
12	Huawei	IM (QQ)	[73.29]	[23.40]	[0.2538]	[0.2899]
13	Intel	Background (multi-app: skype/gtalk/twitter/weather/stock) – A	[6.02]	[12.53]	[0.0560]	[0.1041]
14	Intel	Background (multi-app: skype/gtalk/twitter/weather/stock) – B	[5.34]	[8.97]	[0.0578]	[0.0813]
15	Intel	Background (multi-app: skype/gtalk/twitter/weather/stock) – C	[5.52]	[10.15]	[0.0564]	[0.0851]
16	Intel	Background (multi-app: skype/gtalk/twitter/weather/stock) - D	[5.78]	[10.53]	[0.0606]	[0.0897]
17	Intel	Background (single-app: skype)	[9.11]	[6.86]	[0.1093]	[0.0850]
18	Intel	Background (single-app: google talk)	[10.06]	[1.73]	[0.0344]	[0.0271]
19	Intel	Background (single-app: yahoo messenger)	[1.16]	[3.77]	[0.0353]	[0.0358]
20	Intel	Background (single-app: facebook)	[3.23]	[1.01]	[0.0063]	[0.0096]
21	NSN	Background (facebook android)	30.2576	5.7468	0.0459	0.0454
22	NSN	Background (facebook iOS)	18.6777	14.1180	0.1005	0.0845
23	NSN	Background (facebook symbian)	20.2047	6.2728	0.0281	0.0205
24	NSN	Background (nimbuzz gtalk android)	0.4304	0.4599	0.0064	0.0067
25	NSN	IM (android)	16.9293	14.3582	0.1666	0.1773
26	NSN	IM (iOS)	14.1203	12.6267	0.1351	0.1496
27	NSN	Background (skype android)	1.8226	1.9618	0.0282	0.0293
28	RIM	Background (A1) – music store, facebook, maps, weather app	2.83	2.63	0.061	0.059
29	RIM	Background (A2) – music store, facebook, maps	6.81	3.41	0.088	0.095
30	RIM	Background (A3) – facebook	20.51	10.39	0.143	0.21
31	RIM	Background (A4) – skype	21.1	18.38	0.289	0.346
32	RIM	Background (A5) – skype	13.76	21.43	0.222	0.391
33	RIM	Background (B1) – skype, facebook, weather, stocks, application store	150.35	71.69	0.985	1.028
34	RIM	Background (B2) – skype, facebook, weather, stocks, application store	96.61	45.44	0.364	0.451
35	RIM	Background (B3) – facebook, youtube, email, weather, maps, app^{n} store	72.79	54.41	0.288	0.465
36	RIM	Background (B4) – windows live messenger	171.38	63.83	0.505	0.657
37	RIM	Background (B5) – facebook	30.09	16.56	0.127	0.176
38	RIM	Background (B6) – browser page, windows live messenger, skype, email	79.85	157.53	0.523	1.149
39	RIM	Background (B7) – browser page, skype, email	10.08	38.82	0.191	0.453
40	RIM	IM (conversation 1, application A)	19.55	19.2	0.167	0.199

Trace -ID	Source Company	Description	Mean Rate (Bytes/s)		Mean IP Packets Per Second	
			DL	UL	DL	UL
41	RIM	IM (conversation 2, application A)	28.35	24.86	0.233	0.266
42	RIM	IM (conversation 3, application A)	22.17	20	0.183	0.214
43	RIM	IM (conversation 4, application A)	27.7	24.76	0.214	0.306
44	RIM	IM (conversation 5, application B)	53.19	38.47	0.318	0.401
45	RIM	IM (conversation 6, application B)	23.07	77.04	0.182	0.241
46	RIM	IM (conversation 7, application C)	17.38	24.32	0.167	0.174
47	RIM	Content pull (1) – phone	7453	1075	7.62	6.84
48	RIM	Content pull (2) – phone	5754	788	5.55	5.19
49	RIM	Content pull (3) – tablet	21048	1043	16.91	9.84
50	RIM	Content pull (4) – tablet	28116	691	20.05	9.59
51	RIM	Content pull (5) – tablet	38332	1160	28.06	17.35
52	RIM	Content pull (6) – phone	29302	1180	22.52	14.95
53	RIM	Content pull (7) – phone	16297	1004	13.03	9.75
54	RIM	Content pull (8) – tablet	4133	474	4.31	4.45
55	RIM	Content pull (9) - tablet	61709	1632	45.53	26.65
56	Samsung	Background – android, facebook	16.069	6.717	0.026	0.041
57	Samsung	Background – android, skype	9,968	13.435	0.107	0.129
58	CMCC	IM – QQ	18.25	5.53	0.066	0.089
59	Renesas	Background – android (facebook, skype, e-buddy, google talk, weather, news)	[152.04]	[55.04]	[0.7661]	[0.6719]
60	Renesas	Background – maemo (kweetaur [twitter], pidgin [gtalk / MSN messenger])	[199.35]	[40.13]	[0.3616]	[0.3767]
61	NTT DoCoMo	Background - OS only, no application traffic, android	[0.031]	[0.0917]	[0.0006]	[0.0012]

A.2 Additional Traffic Sources Used for Evaluation

Table A.2-1: Additional Traffic Sources Used for Evaluation

Trace-ID	Source Company	Description	Mean Rate (Bytes/s)		Mean IP Packets Per Second	
			DL	UL	DL	UL
A	Huawei	R2-116167, Background Trace, Appendix 6.2				
B	Huawei	R2-116167, IM Trace, Appendix 6.3				
C	Nokia Corporation, Nokia Siemens Networks	R2-120367, Burst model with geometric distribution of inter-arrival times				
D	Renesas Mobile Europe Ltd	R2-120578, Burst model with geometric distribution of inter-arrival times				

Annex B: Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
2011-09					Initial draft version capturing the outcome of RAN2#75	---	0.0.0
2011-10	R2 #75b	R2-115247			Addition of assigned TR number	0.0.0	0.0.1
2011-11	R2-#76	R2-115597			Inclusion of traffic scenario CDF data	0.0.1	0.0.2
2011-11	R2 #76	R2-115598			Adoption of changes in v0.0.2	0.0.2	0.1.0
2011-11	R2 #76	R2-116504			Agreements made at RAN2 #76	0.1.0	0.1.1
2011-11	R2 #76	R2-116559			Adoption of changes in v0.1.1	0.1.1	0.2.0
2012-02	R2 #77	R2-121008			Inclusion of text proposal on RRC state transitions and mobility signalling. Also editorial changes.	0.2.0	0.2.1
2012-02	R2 #77	R2-121016			Adoption of changes in v0.2.1	0.2.1	0.3.0
2012-03	R2#77b	R2-121952			Updates following RAN2#77bis	0.3.0	0.3.1
2012-03	R2#77b	R2-121976			Adoption of changes in v0.3.1	0.3.1	0.4.0
2012-05	R2#78	R2-123124			Updates following RAN2#78	0.4.0	0.4.1
2012-06	R2#78	R2-123134			Updates following email discussion [78#06]	0.4.1	0.4.2
2012-06	R2#78	R2-123161			Further updates following email discussion [78#06]	0.4.2	0.4.3
2012-06	R2#78	R2-123162			Adoption of changes in V0.4.3	0.4.3	1.0.0
2012-08	R2#79	R2-124266			Updates including changes agreed at RAN2#79	1.0.0	1.0.1
2012-08	R2#79	R2-124298			Updates following email discussion [79#13]	1.0.1	1.0.2
2012-08	R2#79	R2-124299			Adoption of changes in V1.0.2	1.0.2	2.0.0
2012-09	RP-57	RP-121154	-	-	Approved at TSG RAN #57 and put under Change Control	2.0.0	11.0.0