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Technical Report

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Solutions for energy saving within UTRA Node B
(Release 11)

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Foreword

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

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1 presented to TSG for information;

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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

Energy saving is important for operators for operational efficiency. Energy consumption is a significant operational cost factor for operators. In developing markets up to 30% of OPEX is spent on energy. Energy efficiency is also of concern for our environmental objectives. For Macro base station, base station could account up to 80% of CO2 emission in a mobile network. Smaller cost effective nodes such as FemtoCells and PicoCells are increasingly being deployed. Whilst these nodes require less power budget, they provide smaller coverage area. With increased data rate and more denser networks, need for energy efficiency is expected to increase further and so is the requirement for low energy base station technology. There is an increased focus on identifying opportunities for energy efficiency now then ever.

1 Scope

The present document summarizes the study done under the SI “Solutions for energy saving within UTRA Node B” defined in [1] by listing technical concepts addressing the objectives of the study item (see below), analysing these technical concepts and selecting the best solution (which might be a combination of technical concepts).

The objective is to do an initial study to identify potential solutions to enable energy saving within UMTS Node-Bs, and do light initial evaluation of the proposed solutions, with the aim that a subset of them can be taken forward for further investigation as part of a more focused study in 3GPP.

The main objective is to save power of RBS but other savings are also to be investigated. Preference for solutions to be studied can be prioritized as follows.

a) no impact to legacy or new UEs,

b) no impact to legacy but impact to new UEs,

c) impact to both, but minimise impact to legacy.

Solutions that provide energy saving for UMTS NodeB are captured in this Technical report including the ones that do not require specification changes. -Energy saving of site support solutions and NodeB peripheral parts (e.g. rectifier, backup system, Cooling etc) are outside the scope of RAN1 studies.

“Non-backward compatible” techniques are not excluded from discussion at this stage; the impact of the “non-backward-compatibility” on legacy terminals should be assessed.

The present document provides the base for the following preparation of change requests to the corresponding RAN specifications if any solution are identified as beneficial require specification changes.

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*.

[2] RP-091439 Study Item “Solutions for energy saving within UTRA Node B” Vodafone et all…3GPP RAN #46

[2] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[3] 3GPP TS 25.211: "Physical channels and mapping of transport channels onto physical channels (FDD)".

[4] 3GPP TS 25.212: "Multiplexing and channel coding (FDD)".

[5] 3GPP TS 25.213: "Spreading and modulation (FDD)".

[6] 3GPP TS 25.214: " Physical layer procedures (FDD)".

[7] 3GPP TS 25.215: "Physical layer – Measurements (FDD)".

[8] 3GPP TS 25.306: "UE Radio Access Capabilities".

[9] 3GPP TS 25.308: "UTRA High Speed Downlink Packet Access (HSDPA); Overall description; Stage 2".

[10] 3GPP TS 25.309: "FDD Enhanced Uplink; Overall description; Stage 2".

[11] 3GPP TS 25.321: "Medium Access Control (MAC) protocol specification".

[12] 3GPP TS 25.331: "Radio Resource Control (RRC) Protocol Specification".

[13] 3GPP TS 25.433: "UTRAN Iub Interface NBAP Signalling".

[14] 3GPP TS 25.133: "Requirements for Support of Radio Resource Management (FDD)".

[15] ETSI TS 102 706, "Energy Efficiency of Wireless Access Network Equipment".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the [following] terms and definitions [given in ... and the following] apply.

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 following abbreviations apply:

ACK	Acknowledgement
CQI	Channel Quality Indicator
CRC	Cyclic Redundancy Check
DCH	Dedicated Channel
DL	Downlink
DPCCH	Dedicated Physical Control Channel
DPCH	Dedicated Physical Channel
DPDCH	Dedicated Physical Data Channel
DTX	Discontinuous Transmission
E-DCH	Enhanced Dedicated Channel
E-DPCCH	E-DCH Dedicated Physical Control Channel
E-DPDCH	E-DCH Dedicated Physical Data Channel
E-AGCH	E-DCH Absolute Grant Channel
E-HICH	E-DCH HARQ Acknowledgement Indicator Channel
E-RGCH	E-DCH Relative Grant Channel
F-DPCH	Fractional Dedicated Physical Channel
HSDPA	High Speed Downlink Packet Access
HS-DSCH	High Speed Downlink Shared Channel
HS-PDSCH	High Speed Physical Downlink Shared Channel
HS-SCCH	High Speed Physical Downlink Shared Control Channel
NACK	Negative Acknowledgement
P-CCPCH	Primary Common Control Physical Channel
RBS	Radio Base Station
RL	Radio Link
S-CCPCH	Secondary Common Control Physical Channel
SCH	Synchronisation Channel
SIR	Signal-to-Interference Ratio

TFC	Transport Format Combination
TPC	Transmit Power Control
TTI	Transmission Time Interval
UE	User Equipment
UL	Uplink
UTRAN	UMTS Terrestrial Radio Access Network

4 Scenarios

<This section describes all the scenarios that will be studied in energy saving. The scenarios should consider deployment, UTRAN configuration (e.g. MIMO/non MIMO, DC/non DC, macro cell/micro cell), cell load, backward compatibility to a specific UE release, etc.>

RBS configuration specified in [15] is to be used as a baseline. Below are list of aspects that could be used to characterise the energy saving scenarios:

- Deployment and coverage:
  - UTRAN only, single cell, single carrier coverage
  - UTRAN only, single cell, multi-carrier coverage
  - UTRAN only, multiple inter-frequency cells with different coverage (e.g. hot spot and overlay network)
  - Inter-RAT multiple cell Coverage (e.g. UMTS/GSM or UMTS/LTE)
- NodeB configuration
  - Number of sectors and carriers
  - MIMO / non-MIMO
  - NodeB type: Macro NodeB (Concentrated, Distributed), Home NodeB
  - single-carrier, dual-carrier, multi-carrier.
- Assumptions on traffic load and type:
  - Traffic load: empty cell, low, medium, high
  - Number of active users
  - Traffic variation: static, dynamic
  - Traffic type: Mix of R99 HSDPA and HSUPA

5 Energy Consumption of UMTS Node-Bs

<This section contains a qualitative analysis of energy consumption breakdown of current UMTS Node-Bs for different antenna/carrier configurations, NodeB topologies and DL and UL loading scenarios.>

The components listed below are the main parts in an NodeB energy consumption breakdown, containing BBU, REs, power supply, coaxial feed, and other related consumptions. The relation in Table 1 is summarized based on a variety of configurations of macro NodeBs under a low load assumption specified as 10% in [15].

Table 1: Power Consumption breakdown of an UMTS NodeB

UMTS NodeB power consumption	Qualitative contribution to Total Power Consumption

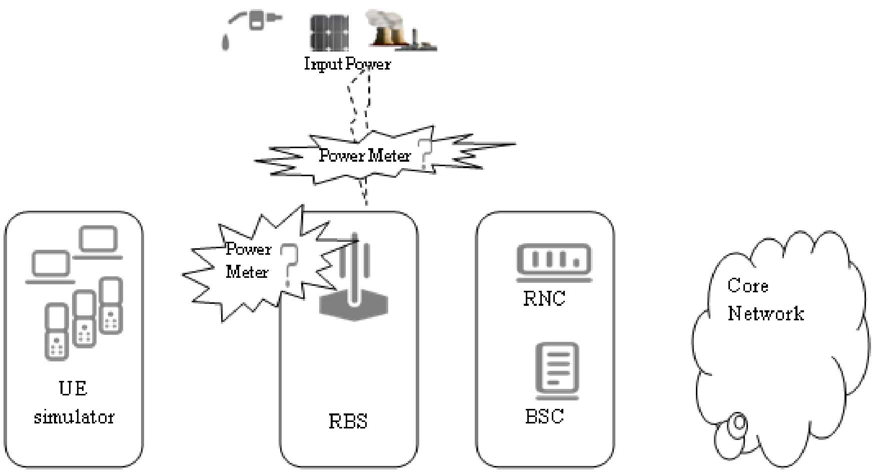
Base Band Unit (BBU)	Medium
Radio Equipments (REs)	Big
Primary DC Power Supply (i.e. rectifiers, battery)	Medium
Coaxial feed pressurization/dehydration	Medium (varying with feeder length and diameter)
Other related consumption(like fan, lighting, alarm, etc.)	Small (under typical environmental conditions)

From the Table 1, BBU and REs correspond to the biggest part of the total power consumption and should thus be the main focus of this study.

However, even if those elements correspond to the main consumption from a qualitative point of view regardless of the NodeB type and configurations, their absolute power consumption is actually very different for the different configurations, e.g. MIMO and non-MIMO, concentrated and distributed NodeB. Therefore, the actual NodeB configuration still plays an important role for finding suitable energy saving solutions and is an important aspect in the definitions of the scenarios as outlined above

6 Metrics for Evaluation

<This section describes how to evaluate the solutions and that the rules for adopting energy saving solution.>



- Metrics and Evaluation to be based on ETSI TS 102 706 [15]
- Energy efficiency shall be a measure of
    - Average power drawn from the input voltage source
    - Long term average RF output power transmitted at each of the antenna port

7 Technical Concepts

This section describes and analyses the suggested technical concepts addressing the problem described by the study item “Solutions for energy saving within UTRA Node B” defined in [1].

7.1 Dormant mode

7.1.1 Description of the concept

It may be possible to obtain significant energy savings by switching off one or more carriers. Even if a downlink carrier cannot be switched off, there could be significant energy savings by just reducing its transmit power.

Deactivation triggered by the RNC: The CRNC may control the carrier deactivation on a relatively slow time basis by removing the cell completely or moving it to dormant mode [13]. Then Node B can switch off the carrier under completely controlled circumstances since no SRNC will attempt to configure UEs with that cell.

Any UEs within the cell would need to move to some other cell, e.g. a different carrier from the same Node B or to a different Node B. If the carrier is deactivated in an orderly fashion, e.g. by ramping down the power during a suitable time period before switching off completely, the normal mobility procedures should result in handovers (soft handover, inter-frequency handover or IRAT handover) and cell reselections from the cell being deactivated to other cells available to the affected UEs. This power ramping is a Node B implementation issue although various enhancements to the control signaling over the network interface(s) can also be envisioned.

Deactivation triggered by the Node B: If there are no UE(s) configured with a particular carrier as its primary carrier, then Node B may be able to switch off that carrier autonomously already within the existing standard if it knows that there are other carriers with fully overlapping coverage or that there can be no UEs camping on that carrier. If the carrier serves as the secondary carrier for a MC-HSPA UE, Node B may choose to send an HS-SCCH order for secondary carrier deactivation to that UE to make the UE stop monitoring the secondary carrier before Node B actually switches off the carrier. Switching off the carrier will not only save energy but also reduce the inter-cell interference. Then, whenever the carrier is needed again, Node B can switch on the carrier and it may also choose to send HS-SCCH orders for secondary carrier activation to MC-HSPA UEs in the cell.

In order to increase the likelihood that a carrier can be deactivated, various enhancements to the control signaling over the network interface(s) or the air interface can be envisioned. However, such enhancements have not been studied in detail and are not discussed further here.

7.1.2 Analysis of the concept

Deactivating a carrier may make it possible for Node B to either power down or completely shut off one of its PAs which may give significant power savings. The savings are highly implementation dependent, in particular the case when a multi-carrier PA (MCPA) is employed.

For some PA implementations, frequent deactivation may have a negative impact on the mean time between failures (MTBF). However, PA implementations without this drawback are feasible.

If both downlink carrier(s) and uplink carrier(s) can be switched off, this could allow for energy savings on both the transmitter side and the receiver side in Node B.

When a carrier is deactivated, any performance gains from using this carrier as a secondary carrier for a UE configured for MC-HSPA operation will disappear. When the CPICH and any other common channels are switched off there may be a significant reduction in inter-cell interference for all users on that carrier.

7.1.3 Pros & Cons of the concept

Pros:

- The potential energy saving is significant.
- Switching off CPICH and other common channels may give a significant reduction in inter-cell interference for all users.

- The concept does not require standard changes although enhancements with standard impact can also be envisioned.

Cons:

- When a carrier is deactivated, the load on the remaining carriers may increase correspondingly.
- If all carriers transmitted from a Node B are deactivated there may be a negative impact on the coverage and/or capacity.
- When a carrier that serves as a secondary carrier to a MC-HSPA UE is deactivated, the cell and user throughput gains from MC-HSPA disappear.

7.1.4 Open issues of the concept

- Impact on the performance of cell selection and mobility procedures in the UE when one or more carriers are deactivated

7.2 Secondary antenna deactivation

7.2.1 Description of the concept

For a Node B that supports MIMO, it may be possible to obtain substantial energy savings by switching off antenna 2 completely, since switching off an antenna typically means that a PA can be switched off. This will not only save energy but also reduce both the intra-cell and inter-cell interference.

Deactivation triggered by the RNC: The CRNC may control the secondary antenna deactivation on a relatively slow time basis by reconfiguring the cell to single-antenna transmission using existing control signaling. All UEs within the cell configured for MIMO reception or Tx diversity reception should also be reconfigured to reception of single-antenna transmissions. Then Node B can switch off antenna 2 under completely controlled circumstances. This means that the MIMO and Tx diversity features are not being offered to UEs in the cell. No SRNC will attempt to configure UEs with MIMO or Tx diversity in the cell. The trigger to switch between single-antenna transmission and dual-antenna transmission could be based on e.g. the estimated cell load level(s). Reconfiguration by the RNC is already supported by the standard.

Deactivation triggered by the Node B: It is also possible for Node B to autonomously deactivate the secondary antenna. If the cell is configured with dual-antenna transmission with P-CPICH on antenna 1 and S-CPICH (not P-CPICH) on antenna 2 but there are no UE(s) configured for MIMO reception or Tx diversity reception in the cell, then the Node B may switch off antenna 2 autonomously already within the existing standard and apply single-antenna transmission. If the Node B applies a power balancing network to achieve power balancing between PAs connected to different antennas, then the power balancing network would need to be disabled when one of the PAs is deactivated. Whenever a UE configured with MIMO or Tx diversity arrives in the cell, Node B can revert to dual-antenna transmission. Thus the basic concept of autonomous secondary antenna deactivation has no impact on the standard.

In order to increase the likelihood that the secondary antenna can be deactivated, various enhancements to the control signaling over the network interface(s) or the air interface can be envisioned. However, such enhancements have not been studied in detail and are not discussed further here.

7.2.2 Analysis of the concept

Deactivating the secondary antenna may make it possible for Node B to either power down or completely shut off one of its PAs. In this case it may be possible to save up to half of the power consumption of the PAs, which is typically a substantial part of the total power consumption of Node B.

For some PA implementations, frequent deactivation may have a negative impact on the mean time between failures (MTBF). However, PA implementations without this drawback are feasible.

When the secondary antenna is deactivated, any performance gains from MIMO or Tx diversity will disappear. When the S-CPICH is switched off this may give a significant reduction in inter- and intra-cell interference for all users. No other impacts on UEs are expected.

The secondary antenna is assumed to be deactivated seldom enough not to have any significant impact on the primary antenna transmission. It is also believed that the Node B receive diversity will not be negatively affected by the switching on the transmit side.

7.2.3 Pros & Cons of the concept

Pros:

- The potential energy saving is substantial.
- Switching off S-CPICH may give a significant reduction in inter- and intra-cell interference for all users.
- The concept of autonomous secondary antenna deactivation does not require standard changes although enhancements with standard impact can also be envisioned.

Cons:

- The concept only applies to systems with two transmit antennas at Node B.
- When the secondary antenna is deactivated, MIMO and Tx diversity have to be deactivated which means that the cell and user throughput gains from MIMO and Tx diversity disappear.

7.2.4 Open issues of the concept

- No open issues

7.3 Power control of common channels

7.3.1 Description of the concept

In current UMTS system, the transmit power of common channels is statically configured based on the cell coverage and is not intended to change dynamically based on UE locations. This leads to situations when the common channels are broadcast to cell edge even if there are no UEs receiving them. If in these cases the common channel transmit power could be reduced it would reduce the total power amplifier output power that in some PA implementations could lead into savings in PA energy consumption.

Figure [X1] and Figure [X2] illustrate the actual cell coverage (shadowing) with normal and reduced common channel powers respectively. The figure [X2] shows the common channel coverage areas optimized to reach all active UEs. One considered enhancement facilitating the common channel power control is using UE provided measurement reports or requests for controlling the common channel power.

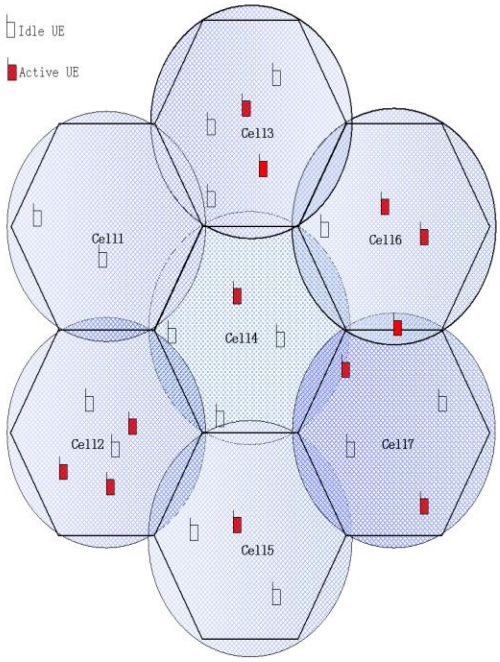


Figure [X1]: Cell coverage without power control of common channels, all UEs are within the coverage

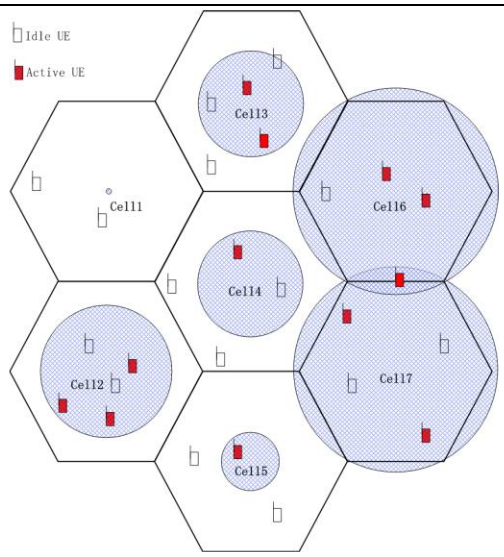


Figure [X2]: Cell coverage with power control of common channels, all active UEs are within the coverage while number of idle UEs fall out of coverage

7.3.2 Analysis of the concept

Node B energy saving potential: Similar transmit power reductions in common channels can be obtained from high load to no load situations. During high load the data channels dominate the transmitted power, hence the percentage of transmit power reductions in common channels would be bigger during low to no load situations than that during high load. In some PA implementations the bulk of the energy is consumed if the PA cannot be completely powered off, thus the actual energy saving potential of the feature may be limited.

Impact on UE power consumption: For UE-assisted power control of common channels, UE power consumption is slightly increased due to the need to send occasional signal to NodeB. The uplink load would also be possibly impacted.

Impact on mobility of active UE: The neighbour cell measurements would not be possible if the neighbour cell SCH/P-CPICH power is reduced. For UE-assisted power control of common channels, the UE would need to e.g. based on degrading own cell start broadcasting a high-power signal and hope there is a neighbour cell that can hear it. The normal power control in UE is not impacted.

Impact on mobility of idle or out-of coverage UE: The UE would not be able to detect a cell at the edge of the potential coverage if the common channel powers are lowered. UE falling out of cell coverage due to lowered P-CPICH power would consider itself out-of-coverage and possibly lose service.

7.3.3 Pros & Cons of the concept

Pros:

- Energy saving gain with some PA implementations.
- Can be applied in all scenarios described in section 4.

Cons:

- Non-backward compatible with legacy UE

- Possibly have a little impact on power consumption of UE.
- Possibly lead to loss of service for Idle mode and PCH state UEs as well as UEs powering up

7.3.4 Open issues of the concept

- Energy saving potential
- Cell acquisition feasibility during power up
- Possible degradation of Cell_DCH state mobility
- Feasibility of Idle mode and PCH state mobility
- Possible impact to uplink load
- Managing legacy UEs

7.4 Cell DTX

7.4.1 Description of the concept

The power amplifier (PA) is one of the elements in the Node B that consumes a significant amount of power, the ability to transmit discontinuously in a cell (Cell DTX) and turn the PA occasionally off would be an attractive option in saving energy in the network. The Cell DTX functionality should enable the cell to periodically power down the cell. All the downlink channels need to be shut down simultaneously in order to be able to turn off the PA and achieve significant energy saving benefits. The larger the off-duration percentage the overall operation time the larger the energy saving.

A Node B could apply brute force Cell DTX and periodically gate all DL physical channel based e.g. on current loading and a traffic pattern estimate. The UEs in the cell or trying to access the cell would benefit from knowing of any Cell DTX pattern in the serving or neighbour cell. Cell DTX is not envisaged for UEs in Cell_DCH. Additional enhancements in specifications enabling aligning at least some UEs' DRX patterns with Cells' DTX patterns, as shown in Figure X3, have been considered for new UEs.

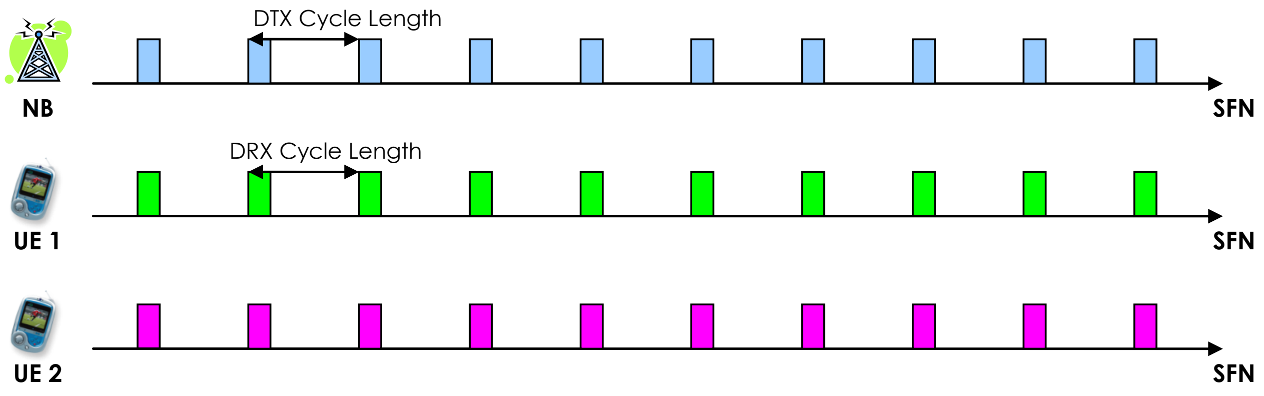


Figure X3: Alignment of UE DRX and Cell DTX patterns

Efforts have been made to align UEs' DRX patterns with Cell's DTX for legacy UEs but significant difficulties in doing this for legacy UEs have been identified especially for UEs in Idle Mode and URA_PCH. Mobility are also studied for legacy UE with some efforts made to enable inbound mobility into a cell performing DTX but it was found to be very difficult especially for UEs in Idle Mode and URA PCH. It was also identified there is impact on legacy UE cell acquisition. Hence, Cell DTX has major backward compatibility issues.

7.4.2 Analysis of the concept

Concept assumes that

- Cell acquisition is possible while Cell DTX is active (performance/feasibility FFS))
- If there are users in Cell_DCH state the Cell_DTX is disabled
- Whenever a paging message needs to be sent to the cell the Cell_DTX is disabled or suffers paging outage

Note that in Release 9 specifications are in conflict of the assumptions made above:

- Cell acquisition requires successful cell search and synchronization as well as succesful system information broadcast reception
- The radio network is not aware of the UE specific core network DRX cycles and it does not know in the cell level where idle mode and URA_PCH state UEs are, and the DRX (paging) cycles of the UEs are distributed in time and cannot be aligned.

7.4.3 Pros & Cons of the concept

Pros:

- Energy saving in the Node B
- UE still able to maintain communication with Node B

Cons:

- Increased cell acquisition time
- Degraded intra-frequency handover reliability
- Compromised inter-frequency / inter-RAT handover capability
- Incompatibility with common channels as designed in WCDMA

7.4.4 Open issues of the concept

- Impact to UE power consumption
- Cell search and acquisition performance impacts due to gated SCH/P-CPICH/P-CCPCH
    - Magnitude of increase in cell acquisition time
    - Feasibility of acquisition of system information broadcast
- Mobility measurement performance impacts due to gated SCH/P-CPICH
    - Intra-frequency neighbour cell measurement reliability
    - Inter-frequency and inter-RAT connected mode measurement arrangement
- Feasibility of being able to force the UE DRX cycle timings by the radio network
    - NOTE: NB may require to “wake up” prior to the UE “wake up” period to ensure that the UE has a stable CPICH prior to UE’s data reception

7.5 <Name of Concept A>

7.5.1 Description of the concept

<Editor's note: How does the concept solve the problems addressed by the SI?>

7.5.2 Analysis of the concept

< Editor's note: Calculations, simulations, gain estimations etc. might be added here.>

7.5.3 Pros & Cons of the concept

Pros:

-

Cons:

<Editors note: UE impacts; including those on legacy UE's, gains and specification impacts should be captured in this section.>

- Cell and User throughput
- UE energy consumption
- Impact to UE RRC states,
- Possibility for UE camping,
- Idle / Connected mode mobility including cell identification
- Call setup latency (e.g. emergency call)

8 Recommendation

This section describes which technical concepts of section 4 are potentially useful for the 3GPP specification.

8.1 Overview of the selected solution

<Editor's note: A summary of which concepts are selected.>

Annex A (informative): Change history

Change history							
Date	Meeting	Doc.	CR	Rev	Subject/Comment	Old	New
2010-02	RAN1 #60	R1-101690	-	-	Skeleton TR Text Proposals for clause 4,5,6 are captured	-	0.0.1
2010-04	RAN1 #60bis	R1-102495	-	-	Text Proposals for clause 4,5,6,7, are captured	-	0.0.2
2010-05	RAN1 #61	R1-103424	-	-	Include TP' on concept of Dormant mode, Secondary antenna deactivation, Power control of common channels and Cell DTX	-	0.0.3
2010-09	RAN#49	RP-101009	-	-	Update to version 1.0.0 on closure of the related study item	0.0.3	1.0.0
2010-09	RAN#49	-	-	-	Release 10 is created further RAN decision to go under change control	1.0.0	10.0.0
2012-09	SP_57	-	-	-	Update to Rel-11 version (MCC)	10.0.0	11.0.0