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Technical Report

Electromagnetic compatibility and Radio spectrum Matters (ERM); Technical characteristics of Smart Metering (SM) Short Range Devices (SRD) in the UHF Band; System Reference Document, SRDs, Spectrum Requirements for Smart Metering European access profile Protocol (PR-SMEP)

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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

The present document includes necessary information to support the co-operation under the MoU between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Postal and Telecommunications Administrations (CEPT).

Introduction

The requirement to wirelessly interconnect Smart Meters is one of the responses to the EC's mandate 441 [i.1] for an open architecture for utility meters. Short Range Device (SRD) technology, has been identified as a candidate technology to interconnect meters to the Wide Area Network (WAN) Access Point (AP).

- The TR 102 649-2 [i.22] identified.
- Preliminary performance requirements for SRDs for use with Smart Meters.
- An uncoordinated time bound access mechanism, with 25 mW. e.r.p. power.

A suggested frequency designation of 873 MHz to 876 MHz which is one of the sub-bands of the 870 MHz to 876 MHz and 915 MHz to 921 MHz duplex pair currently allocated for E-GSM-R and military use.

The present document examines whether the performance requirements, access mechanism and transmitted power currently in use for SRDs are adequate for Smart Meters and opens a discussion on further work required to establish the magnitude of any compatibility issues in sharing the 873 MHz to 876 MHz frequency band.

The present document identifies the key service requirements which will impact the volume of traffic to be transmitted between meter and AP. A mesh network is assumed for the delivery of data between meter and AP as this accommodates the limited power available for data transmission and minimises the number of APs. The mesh traffic is modelled and the expected network performance established. This is then compared with the current SRD regulatory limits.

The discussion on compatibility assumes that the military services will be displaced by E-GSM-R and that it is with this service that the SRDs will share the frequency band. The report examines the potential for co-channel inter-system interference using as a starting point the work undertaken at the BNetzA laboratory at Kolberg in August 2009 [i.25]. Adjacent channel interference has already been considered in TR 102 649-2 [i.22] and is not repeated here.

Intra-system interference from collocated SRD systems is being addressed in CEPT SE 24 under WI23 and although the results of these deliberations are not yet available draft information is available on the CEPT web site. Further work on low duty cycle as a mitigation technique for SRDs has been approved by ETSI and the Special Task Force (STF) 411 expects to complete its work within 9 months. A measurement campaign on Low Duty Cycle requirements was recently completed by the JRC [i.33] and the reader is invited to consider the preliminary results of this work when reviewing clause B.3 on Access mechanisms. These activities will guide the development of future analyses in the present document.

1 Scope

The present document applies to a new class of SRD devices specifically for Smart Metering applications operating in the UHF frequency band from 870 MHz to 876 MHz. It extends the discussion on Smart Metering Performance Requirements in TR 102 649-2 [i.22] and identifies the particular RF performance parameters needed for the operation of these devices.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] M/441: Standardisation Mandate to CEN, CENELEC and ETSI in the field of measuring instruments for the development of an open architecture for utility meters involving communication protocols enabling interoperability.

[i.2] FP7 Research Priorities for the Renewable Energy Sector (March 2005).

[i.3] "The challenges towards the Smart Electricity Grids", Dr. Manuel Sánchez Jiménez, Policy Officer, Unit C.2 Electricity and Gas Markets.

[i.4] San Diego Smart Grid Study Final Report, October 2006, SAIC Smart Grid Team.

[i.5] FM(08)098 Rev 1: "Analysis of the Replies to the questionnaire on the additional spectrum for RFID and SRDs at UHF band".

[i.6] CEPT ERC/Dec(96)04: "ECC Decision of 19 March 2004 on the availability of frequency bands for the introduction of Wide Band Digital Land Mobile PMR/PAMR in the 400 MHz and 800/900 MHz bands Amended the Annex to the Decision 27 June 2008 amended 26 June 2009".

[i.7] CEPT ECC/Dec(04)06: "ERC Decision of 7 March 1996 on the frequency bands for the introduction of the Trans European Trunked Radio System (TETRA)".

[i.8] Smart Meters Co-ordination Group Final Report (Version 0.7 - 2009-12-10): "Standardization mandate to CEN, CENELEC and ETSI in the field of measuring instruments for the development of an open architecture for utility meters involving communication protocols enabling interoperability M/441".

[i.9] ETSI TR 102 898: "Machine to Machine Communications (M2M); Use cases of Automotive Applications in M2M capable networks".

[i.10] ETSI TR 103 055: "Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference document (SRdoc): Spectrum Requirements for Short Range Device, Metropolitan Mesh Machine Networks (M3N) and Smart Metering (SM) applications".

[i.11] ETSI TR 102 691: "Machine-to-Machine communications (M2M); Smart Metering Use Cases".

[i.12] ESMIG: "Smart Metering market and standards", CEN/CENELEC - Madrid, 1st July 2009.

[i.13] ESMA: "Annual Report on the Progress in Smart Metering 2009", v2.0, January 2010.

[i.14] ESMA: "National Perspectives on Smart metering", v1.0 April 2008.

[i.15] "Open Metering System Specification", Volume 1, General Part, Issue 1.2.0/2009-07-17.

[i.16] OMS: "Open Metering System Specification", Volume 2, Primary Communication, Issue 2.0.0/2009-07-20.

[i.17] Tanenbaum A.S.: "Computer Networks", Third Edition, Prentice-Hall, ISBN 0-13-349945-6.

[i.18] ETSI EN 300 220 (all parts) (V2.1.2): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment to be used in the 25 MHz to 1 000 MHz frequency range with power levels ranging up to 500 mW".

[i.19] CEPT ERC/REC 70-03: "Relating to the use of short-range devices (SRD)".

[i.20] CEPT ECC Report 37: "Compatibility of planned SRD applications with currently existing radiocommunication applications in the frequency band 863-870 MHz", Granada, February 2004.

[i.21] ETSI TR 102 649-1: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Technical characteristics of RFID in the UHF Band; System Reference Document for Radio Frequency Identification (RFID) equipment; Part 1: RFID equipment operating in the range from 865 MHz to 868 MHz".

[i.22] ETSI TR 102 649-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Technical characteristics of Short Range Devices (SRD) and RFID in the UHF Band; System Reference Document for Radio Frequency Identification (RFID) and SRD equipment; Part 2: Additional spectrum requirements for UHF RFID, non-specific SRDs and specific SRDs".

[i.23] ETSI ES 202 630: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment to be used in parts of the frequency range 870-876 MHz and 915-921 MHz, with Transmitter Duty Cycle (TDC) restriction and power levels up to 25 mW; Technical characteristics and test methods".

[i.24] NISTIR 6055; NIST construction automation program, Report No 3: "Electromagnetic Signal Attenuation in Construction materials".

[i.25] Feasibility Tests between E-GSM-R and Low Duty Cycle SRD at Kolberg, Germany, 19th to 20th August 2009 Federal Network Agency, Germany.

[i.26] "A Channel Access Scheme for Large Dense Packet Radio Networks"; Timothy J. Shepard; ACM SigComm "96, August 1996, Stanford University California.

[i.27] Netherlands Technical Agreement NTA 8130:2007; "Minimum set of functions for metering electricity, gas, thermal energy for domestic customers".

[i.28] Department of Primary Industries; Advanced Metering Infrastructure, Minimum AMI Functionality Specification (Victoria); September 2008.

[i.29] OPEN meter 7: "Open Public Extended Network Metering", 01/07/2009.

[i.30] CEPT report 19 Report from CEPT to the European Commission in response to the Mandate to develop least restrictive technical conditions for frequency bands addressed in the context of WAPECS; Final Report on 21 December 2007 with editorial revisions on 17 March 2008 and 30 October 2008.

[i.31] Directive 2006/32/EC of the European Parliament and of the Council of 5th April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC.

[i.32] Report on Radio Frequency Compatibility Measurements between UWB LDC Devices and Mobile WiMAX (IEEE 802.16e-2005) BWA Systems; Ispra, July 26-27, 2010.

[i.33] The World Water Meter Report and Database Ed 7 2009 and The Meter Manufacturers Directory Ed 4 2009; ABS Energy Research.

[i.34] Smart Water Meters; Advanced Metering Infrastructure for Water Utilities; Market Drivers, Technology Issues, Deployment Case Studies, Key Industry Players and Market Forecasts; September 2010.

[i.35] Hashemi, "The indoor radio propagation channel", Proceedings of the IEEE, Vol. 81, no. 7, July 1993.

[i.36] A. Rahim, X. Mindong, S. Zeisberg, A. Idriss, A. Finger: "Radio Coverage Measurement and Characterization for Indoor Fixed Radio at 900 MHz and 2450 MHz", 15th IST Mobile and Wireless Communications Summit, Mykonos, Greece, June 2006.

[i.37] J.M. Molina-Garcia-Pardo, A. Martinez-Sala, M.V. Bueno-Delgado, E. Egea-Lopez, L. Juan-Llacer, J. García-Haro: "Channel Model at 868 MHz for Wireless Sensor Networks in Outdoor Scenarios". International Workshop on Wireless Ad Hoc Networks, IWWAN 2005, London, May 2005.

[i.38] Daniel Peña, Rodolfo Feick, Senior Member, IEEE, Hristo D. Hristov, Senior Member, IEEE, and Walter Grote: "Measurement and Modeling of Propagation Losses in Brick and Concrete Walls for the 900-MHz Band". IEEE Transactions on Antennas and Propogation, Vol. 51, No. 1, January.

[i.39] Roger A. Dalke, Christopher L. Holloway, Paul McKenna, Martin Johansson, and Azar S. Ali: "Effects of Reinforced Concrete Structures on RF Communications". IEEE Transactions on Electromagnetic Compatibility, Vol. 42, No. 4, November 2000.

[i.40] ATMEL data sheet AT86RF212.

[i.41] A. Rahim, S. Zeisberg, M.L. Fernandez, A. Finger: "Impact of People Movement on Received Signal in a Fixed Indoor Radio Communications", PIMRC "06, Helsinki, Finland, September 2006.

[i.42] IEC 60309 (all parts): "Plugs, socket-outlets and couplers for industrial purposes".

[i.43] IEC 61851-1: "Electric vehicle conductive charging system - Part 1: General requirements".

[i.44] IEC 62196-1: "Plugs, socket-outlets, vehicle couplers and vehicle inlets - Conductive charging of electric vehicles - Part 1: Charging of electric vehicles up to 250 A a.c. and 400 A d.c.".

[i.45] ETSI TS 102 890 (all parts): "Intelligent Transport Systems (ITS); Facilities layer function".

[i.46] Ofcom: "Award of the band 872-872 MHz paired with 917-921 MHz".

NOTE: Available at: http://stakeholders.ofcom.org.uk/consultations/872_876_mhz/update/

[i.47] BRUSA Elekronik: " Definition and implementation of a global EV charging infrastructure".

NOTE: Available at: http://www.park-charge.ch/documents/EV-infrastructure%20project.pdf.

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

access point: device providing an interface between a Wide Area Network (WAN) and a local network domain

adaptive frequency agility: technique that allows a device to change its frequency of operation automatically from one channel to another

channel: small frequency sub-band within the operating frequency band into which a *Radio Signal* fits

NOTE: Commonly, a *frequency band* is divided into contiguous channels.

duty cycle: for the purposes of the Recommendation ERC/REC 70-03 [i.19], the duty cycle is defined as the ratio, expressed as a percentage, of the maximum transmitter cumulative "on" time on one carrier frequency, relative to a one hour period

NOTE 1: For frequency agile devices the duty cycle limit applies to the total transmission.

NOTE 2: For specific applications with very low duty cycles and very short periods of transmissions, the definition of duty cycle should be subject to study.

gateway: network point of attachment for a node

listen before talk: action taken by a device to detect an unoccupied sub-band or channel prior to transmitting

metering: transmission of metrology information (electricity, gas water and energy) by radio communication

node: network device associated with a Smart Meter

Short Range Devices (SRDs): radio devices which provide either unidirectional or bi-directional communication and which have low capability of causing interference to other radio equipment

NOTE: SRDs use either integral, dedicated or external antennas and all modes of modulation can be permitted subject to relevant standards. SRDs are normally "license exempt".

specific SRDs: SRDs that are used in specific applications

NOTE: E.g. Applications of ERC/REC 70-03 [i.19], annexes 2 to 13.

3.2 Symbols

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

d distance

3.3 Abbreviations

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

AFA	Adaptive Frequency Agility
AMI	Advanced Meter Infrastructure
AMM	Advanced Meter Management
AMR	Advanced Meter Reading
AP	Access Point
BPSK	Binary Phase Shift Keying
C/I	Carrier to interference ratio specified for the victim receiver in dBm
CA	Collision Avoidance
CCA	Clear Channel Assessment
CEPT	European Conference of Postal and Telecommunications Administrations
CSMA	Carrier Sense Multiple Access
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
D.C.	Duty Cycle
DSSS	Direct Sequence Spread Spectrum
e.r.p.	Effective radiated power
EC	European Community
ECC	Electronic Communications Committee
ECS	Electromobile Club of Switzerland
E-GSM-R	Extended GSM for Railways

EN	European Norm
ERC	European Radiocommunication Committee
ESMA	European Smart Metering Alliance
ESMIG	European Smart Meter Interest Group
FHSS	Frequency Hopping Spread Spectrum
GE	General Electric
GSM	Global System for Mobile communications
HAN	Home Area Network
IP	Internet Protocol
ISM	Industrial Scientific and Medical
LAN	Local Area Network
LBT	Listen Before Talk
LDC	Low Duty Cycle
LOS	Line of Sight
MAC	Medium Access Control
MUC	Multi-Utility Controller
NM	Network Management
OQPSK	Offset Quadrature Phase Shift Keying
PL	Path Loss
PMR	Private Mobile Radio
R&TTE	Radio & Telecommunications Terminal Equipment
REC	Recommendation
SRD	Short Range Device
SRDMG	Short Range Device Management Group
STF	Special Task Force
TDC	Transmitter Duty Cycle
TPC	Transmit Power Control
TR	Technical Report
UHF	Ultra High Frequency
WAN	Wide Area Network
WGFM	Working Group Frequency Management

4 Comments on the System Reference Document

None received.

5 Executive summary

5.1 Context

5.1.1 Supply side

Europe's integrated utility network will be subject to substantial restructuring in the coming years as a direct consequence of the ongoing liberalisation of the energy market. The present electricity supply infrastructure, which is characterised by large, centralised power stations, will evolve into a system comprising both centralised and decentralised electricity supplies including micro generators, electric vehicles as well as small and medium sized renewable sources. This process will place new demands on the engineering of these systems, including equipment specification and control. The anticipated rapid growth in the numbers of decentralised micro generators requires an advanced integration strategy to be developed [i.2]. Part of this integration will be a supporting communication network to permit the monitoring and control of these generators as they are switched on and off line. This same network can also be used to assist consumers to make informed choices on their consumption.

5.1.2 Demand side

Consumers are increasingly sensitive to resource consumption and in the case of power, their carbon foot print. Smart Metering is the first step in integrating consumers' wishes with the supply of these resources. It enables consumers to use resources more efficiently; this may be based on time variable tariffs or other incentives related to the demand.

5.1.3 EC Mandate

Smart Metering primarily targets improvement of energy end-use efficiency as defined by Directive 2006/32/EC [i.31], thus contributing to the reduction of primary energy consumption, to the mitigation of CO_2 and other greenhouse gas emissions.

According to the European Commission, Standardisation Mandate M/441 [i.1], to CEN, CENELEC and ETSI, "in the field of measuring instruments for the development of an open architecture for utility meters involving communication protocols enabling interoperability".

> "The general objective of this mandate is to create European standards that will enable interoperability of utility meters (water, gas, electricity, heat), which can then improve the means by which customers' awareness of actual consumption can be raised in order to allow timely adaptation to their demands (commonly referred to as 'Smart Metering')."

Although this strictly defines Smart Metering, it is clear from the first article of the Mandate that its intention far exceeds that of Smart Meters. It particularly requests the development of an "…open architecture for utility meters that supports secure bidirectional communication upstream and downstream … and allows advanced information and management and control systems for consumers and service suppliers."

This intention of the Mandate encapsulates the notion of Smart Grid where computing and communications technologies are integrated with the power-delivery infrastructure.

The Smart Grid is the integration of technologies that permit inter alia [i.3] and [i.4] the:

- coexistence of centralised and decentralised power generation;
- detection and resolution of emerging network issues;
- response to local and system wide inputs;
- rapid communication between peer devices and with centralised and distributed controllers;
- deployment of advanced diagnostics, feedback and control;
- coordination of attached loads and distributed resources.

In all the above cases, messages describing the situation need to be passed from the Smart Meter to the controlled or controlling entity. In circumstances which might compromise the grid reliability a real time response will be required.

5.2 Market Information

There are in excess of 300 million gas and electricity meters alone which require replacing to meet the requirements of M441 and a similar number of water and energy meters. The per-country numbers of gas and electricity meters are shown in annex F.

There are approximately 157 million water meters installed in Europe [i.33] and although there is no legislation driving the adoption of Smart Metering for water it is expected that 31 % of all new water meters installed will be Smart or Smart enabled meters by 2016 [i.34].

5.3 Electric vehicles and their Infrastructure

Many countries are encouraging the sale and promotion of electric vehicles by various means and in a number of European cities there are ongoing activities to support their use.

The French government plans to acquire 50,000 electric cars for use by public companies and local authorities. In Germany, the Minister of Transport announced in November 2009 the support of development of electro-mobility by the German government with 1.4 billion Euros over the next few years.

In September 2009, a contract was placed for the delivery of 100,000 cars before 2016, to be sold in Denmark and Israel. A Danish energy supplier will establish the complete charging infrastructure in Denmark and the Danish government announced reduced taxes for electric cars to support this activity. Also in September, the Spanish government provided 10 million Euros for their program "Movelle" to introduce electrical cars in Spain.

Each of these initiatives to promote the manufacture, sale and use of electric vehicles places demands on the charging infrastructure and associated Smart Metering for customer billing. Although the charging infrastructure has not yet been standardised this is being actively pursued. More details regarding the standardisation of the charging infrastructure are provided in Annex G.

5.4 National Frequency Re-assignments in the UHF band

The frequency band 870 MHz to 876 MHz and its duplex pairing 915 MHz to 921 MHz was the subject of a CEPT review in September 2008 [i.5]. A summary of the re-assignment plans for these frequency bands in the major markets identified in annex F is shown in annex A. The output of this review revealed that this duplex pairing was allocated for digital land mobile applications in accordance with ERC/Dec(96)04 [i.6] and ECC/Dec(04)06 [i.7] and for military use. The common use of this duplex pair within Europe is for tactical military relays.

In the lower and upper band most administrations were of the view that some sharing of part of the band would be possible following co-existence analysis and only if existing services could be protected.

In advance of any harmonised approach to the use of this band the German regulator has to issue a licence to the Deutsche Bahn to operate GSM-R in the band 873 MHz to 876 MHz. OFCOM in the UK recently completed a consultation where it invited interested parties to comment on potential uses and licensing schemes for the frequency band 872 MHz to 876 MHz and the complementary duplex frequencies. At the time of writing this document the final results of this consultation were not expected.

5.5 The Issues

The present document investigates the use of the frequency allocation 873 MHz to 876 MHz for Smart Metering SRDs.

- The distance between meters in some deployments may be greater than the radio range achievable with 25 mW e.r.p.
- A 1 % duty cycle limit may not be appropriate under all circumstances for Smart Metering applications.
- Smart Metering applications may require data rates in excess of 100 kbps.
- A channelisation scheme consistent with E-GSM-R is required for spectrum efficiency.

5.6 Summary of requirements

From the comparison of the published performance requirements of SRDs in the frequency band 870 MHz to 876 MHz with the Smart Meter protocol requirements developed in clause B.3, the following operating parameters have been derived:

Table 1: Proposed Operating Parameters

Parameter	Value
Power	100 mW e.r.p.
Channelisation	200 kHz
Duty Cycle	Overall 2,5 % measured over a specified interval without peak limit in any sub-interval (see note)
Access Mechanism	Aloha or CSMA/CA
NOTE: Subject to the outcome of compatibility studies	

5.7 Summary of recommendations and requested EC, ECC and ETSI action

ECC is requested to:

- Undertake studies on the proposals for new spectrum for high performance UHF SRD systems for Smart Metering.
- Complete these studies within a time frame of 12 months.

EC actions is requested to:

- Harmonize European conditions for the availability and use of the radio spectrum for such SRDs.

It is recommended that ETSI ERM_TG28:

- Finalise the ES 202 630 [i.23] that would then be a good basis for a new harmonised standard for Specific SRDs.

6 Current Requirements for SM SRDs

6.1 Overview of published performance requirements for specific SRDs using the frequency band 870 MHz to 876 MHz

SRDs are presently not allocated to the frequency band 870 MHz to 876 MHz. Of the limited reference documents available, [i.19], [i.20], [i.21] and [i.22], it is possible to extract some information on the likely performance parameters which would be used in this band. The most important of these, addressing operational parameters and test methodology, are TR 102 649 parts 1 and 2, [i.21] and [i.22] and draft ES 202 630 [i.23]. These are addressed in turn below.

6.1.1 Overview of the TR 102 649 parts 1 and 2

TR 102 649-1 [i.21] summarises the current use by SRDs of the frequency band 865 MHz to868 MHz and recommends the reassignment of certain frequency allocations for RFID which optimises the use of this band. TR 102 649-2 [i.22] identifies the additional spectrum for UHF RFID, non-specific and specific SRDs to operate in the frequency band 870 MHZ to 876 MHz. This band has been split into two sub-bands:

- a non-channelised sub-band between 870 MHz to 873 MHz, for the use of non-specific SRD using the same access rules as for the band 863 MHz to 870 MHz;
- a channelised sub-band between 873 MHz to 876 MHz with a channelisation interval of 200 kHz.

In the upper sub-band an occupied bandwidth of 150 kHz is promoted as suitable for a data rate of 100 kbps with a relaxation to 250 kHz to accommodate meters used for metering heat energy where frequency drift owing to temperature variations is likely. It is recognised that owing to the indoor location of the majority of metering devices there will be some attenuation from the structure of the building which will provide interference mitigation. Although no specific access mechanism is identified for this band a duty cycle limit with maximum on and minimum inter-packet off times is defined.

A summary of the proposal for this sub-band is given in Table 2 and Figure 1.

Table 2: Summary of proposed characteristics for SRDs

Frequency Band (G6)	Power	Duty Cycle	Channel bandwidth	Notes
873 MHz to 876 MHz specific SRDs. Short Burst Telegrams	≤1 mW. e.r.p. (to be studied) ≤25 mW. e.r.p. ≤100 mW. e.r.p.	Up to 5 % D.C. Up to 1 % D.C. Up to 0,1 % D.C.	No channel spacing	Narrow/wideband, DSSS with 0,1 % duty cycle permitted. FHSS duty cycle and T_{on} time of hops to be studied [i.20]
NOTE: For the power and duty cycle values of the frequency range **G6**, the trade-off varying power and duty cycle can be interpolated from Figure 1.				

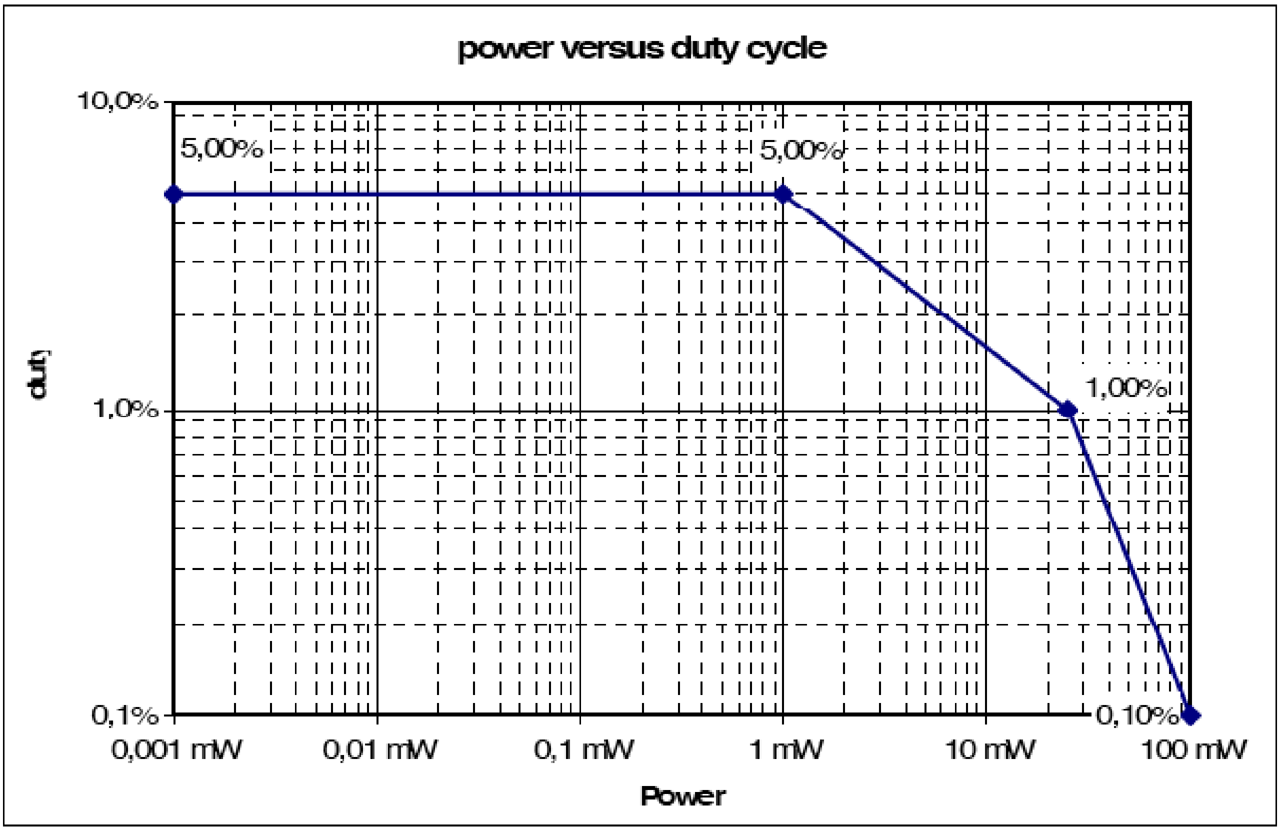

Figure 1: Allowed P_{erp} versus duty cycle in the sub-band 873 MHz to 876 MHz

6.1.2 Overview of draft ES 202 630

This ES provides the European profile for SRDs in the frequency band 870 MHz to 876 MHz. The work considers the E-GSM-R standardisation being undertaken in ETSI TC RT. The ES 202 630 [i.23] is applicable to all major equipment types including metering devices. The profile for radiated power, channel spacing and duty cycle is shown in Table 3 and transmitter duty cycle is shown in Table 4.

Table 3: Maximum radiated power, channel spacing and duty cycle requirement

Frequency Band	Applications	Maximum radiated power (e.r.p.)/power spectral density	Channel Spacing	Transmitted duty cycle
870 MHz to 873 MHz	All	25 mW	None	1 % duty cycle or LBT +AFA
873 + 0,2n MHz; 1≤n≤14	All	100 mW	200 kHz	See Table 4

Table 4: Transmitter duty cycle

TDC parameter	Value
Maximum Tx on	≤ 25 ms
Minimum Tx off	≥ 500 ms
Maximum accumulated transmission time (Tx on)	18 s in one (1) hour
NOTE: The maximum accumulated transmission time takes into account the presence of 10 simultaneous SRD TDC devices and is needed to avoid aggregated interference effects.	

7 Future Requirements for SM SRDs

7.1 Introduction

As identified in CEPT report 19 [i.29], the frequency band 870 MHz to 876 MHz may be in use either by E-GSM-R or by the military. Where it is used by the military any re-use of this allocation by SRDs would be on a country-by-country basis. However, for the purposes of this discussion it is assumed that E-GSM-R, whose basic characteristics are known, is deployed across Europe.

7.2 Channelisation

The proposed channelisation scheme of clause B.3 of TR 102 649-2 [i.22] is 250 kHz specifically to accommodate heat meters which represent a small proportion of all meters. Although a channel of 250 kHz will support a data rate of 100 kb/s, this channelisation is at variance with the current scheme for EGSM-R whose frequency allocation is targeted for the SRD service. Moreover the use of such a scheme will result in the loss of valuable spectrum for those devices which need only 200 kHz bandwidth for a data rate of 100 kb/s. It is suggested that for those applications which need the higher bandwidth to accommodate a data rate of 100 kb/s that these occupy two adjacent channels. Overall this would optimise the use of the available frequency sub-band from 873 MHz to 876 MHz.

7.3 Power

It is argued in annex E that the current limit of 25 mW might be raised in this band by 6 dB to10 dB at no detriment to existing services provided a deployment separation of 10 m is maintained between SRD and E-GSM-R base station. According to TR 102 649-2 [i.22] and illustrated in Figure 1, such a power increase would be permitted but only at the expense of lower duty cycle. Such a scheme has advantages and disadvantages for spectrum utilisation.

The advantages would be to:

- extend the range of any transmission and hence reduce the number of hops to reach a WAN AP;
- reduce on-air time owing to better link margin.

The disadvantages would be to:

- increase the necessary data rate of any transmission to respect the duty cycle;
- require wider channels for the higher data rate and hence reduce the efficiency of spectrum utilisation.

It is further argued in clause B.4 that for high density dwellings where re-enforced concrete is used that a minimum power of 100 mW e.r.p. will be essential for the successful deployment of Smart Metering.

7.4 Duty Cycle

For spectrum efficiency, RF parameters consistent with the E-GSM-R chanelisation scheme are required. The Kolberg test results [i.25] show that SRD co-existence with E-GSM-R at a 2,5 % duty cycle is possible with time constrained transmission bursts. This duty cycle limit is also compatible with Smart Metering Systems Requirements at data rates in excess of 100 kbps. It is technically feasible to constrain a 100 kbps transmission within a 200 kHz channelisation scheme.

8 Conclusions

In TR 102 649-2 [i.22] the duty cycle and power requirements of a single metering device were considered. The present document considers the deployment scenarios of large numbers of Smart Metering devices.

The analysis of clause B.3.3 shows that for low offered traffic loads an Aloha access mechanism is adequate and that Carrier sense multiple access with collision avoidance (CSMA/CA) schemes offer no increase in spectrum efficiency.

Using the Service Requirements of clause B.2 the analysis in clause B.3 shows that:

- an AP can support up to 300 nodes using the current SRD duty cycle limits;
- this can be extended to 1 000 nodes using the 2,5 % duty cycle derived from the Kolberg co-existence tests [i.25]. This figure of 2,5 % is fully consistent with the draft ES 202 630 [i.23];
- in either case a data rate of 100 kbps is required. This data rate is consistent with the channelisation scheme of 200 kHz present in the E-GSM-R band 873 MHz to 876 MHz.

As noted in clause B.3.2 this increase in the number of nodes per AP will reduce the overall operating costs of the network.

However, the proposed chanellisation scheme of annex B of TR 102 649-2 [i.22] recommends 250 kHz which is at variance with the established 200 kHz channelisation scheme of E-GSM-R. Applications requiring additional occupied bandwidth should make use of multiple 200 kHz channels.

It is noted that the limitation on transmit time for duty cycle limited devices operating in the frequency band 873 MHz to 876 MHz is inconsistent with the frequency band 870 MHz to 873 MHz. Furthermore no technical justification is provided for this limit in either case and subject to results of compatibility studies, it is recommended that no such limit is imposed on Smart Metering.

A transmit power increase of 6 dB to 10 dB is feasible if an exclusion perimeter is maintained from any railway thoroughfare and will under most circumstances permit the operation of Smart Meters even when deployed in high density dwellings of modern construction. The increase in available power will reduce the number of hops to deliver data to the destination, and the number of retransmissions necessary owing to a reduced packet error rate arising from improved link margin.

9 Requested ECC, EC and ETSI actions

ETSI requests ECC to consider the present document, which includes the necessary information to support theco-operation under the MoU between ETSI and the Electronic Communications Committee (ECC) of the EuropeanConference of Post and Telecommunications Administrations (CEPT).

ECC is requested to undertake further studies on the proposals for the frequency band 873 MHz to 876 MHz for high performance UHF SRD systems for Smart Metering. In particular the following parameters should be studied:

- a duty cycle of 2,5 % with no limit applied in any period;
- a power limit of not less than 100 mW e.r.p.;
- the channelisation scheme proposed for SRD devices to correspond to the E-GSM-R scheme.

It is requested that these studies are performed within a time frame of 12 months.

It is recognised that some European countries have military use in the bands which are proposed for these SRD applications whilst in other frequency bands they are being used by railway operators. As part of the requested action, the ECC is therefore invited to consider with these existing users the possibility of SRD use in these bands. It is requested that ERC/REC 70-03 [i.19] be amended to include designated spectrum for the new frequency ranges and applications.

In parallel with an amendment to ERC/REC 70-03 [i.19] and as part of the annual update of the technical annex of the Commission Decision on the technical harmonisation of radio spectrum for use by short-range devices, the SRDMG is requested to seek harmonisation of the band at a European level.

It is recommended that Sub-Technical Committee ETSI ERM TG28 finalise the ES 202 630 [i.23] that would then be a good basis for a new harmonised standard for Specific SRDs.

Annex A: Re-assignment of 870 MHz to 876 MHz and 915 MHz to 921 MHz by National Regulators

Table A.1: Planned re-assignment of frequencies

Country	870 MHz to 876 MHz	915 to 921MHz
DE	Assigned 873 MHz to 876 MHz to EGSM-R	Assigned 918 MHz to 921 MHz to EGSM-R
ES	Assigned to wideband PMR; no re-assignment to SRDs foreseen.	
FR	No re-assignment presently being considered, however 25 mW devices could be envisaged on the basis of co-existence studies.	
I	Currently assigned to various fixed and mobile applications; no re-assignment foreseen on the basis of incompatibilities with deployed military services.	
NL	No re-assignment anticipated.	
PL	No information available.	
UK	Preliminary comments to the OFCOM consultation issued. Potential non-Smart Metering uses from consultation responses: • Broadband Fixed and Mobile (cf DigiWeb in Ireland) • GSM-R - linked with 876,0 to 914,8/921,0 to 959,8 for LTE enhancements • RFID/SRD (from ERM TG28 response) • Emergency Services • Unmanned Airborne Vehicles Further details can be found at: http://www.ofcom.org.uk/consult/condocs/872_876_mhz/update/ [i.46]	

Annex B: Technical requirements

B.1 Typical application scenario

B.1.1 Introduction

Consensus is forming around the functionality of a "typical" Smart Meter. In the Americas, Australia, the UK, and in many jurisdictions in Europe, a Smart Meter typically consists of:

- metrology (e.g. periodic kWh usage);
- power quality determination such as volt/var measurement;
- a "service switch" that can allow for remote connection and disconnection, or load limiting to a particular premise;

Associated with the Smart Meter is a Home Area Network (HAN) interface which allows the consumer to monitor consumption in real-time as well as the status of domestic devices and view other key information such as tariffing.

The services which have been identified by ETSI M2M will communicate with the Smart Meter and other devices connected to the low voltage grid within the home via the gateway. The gateway is the AP for pricing and billing information, power grid status, the coordination of renewables and electric vehicle charging. An example of a Smart Meter environment with supporting infrastructure is shown in Figure B.1.

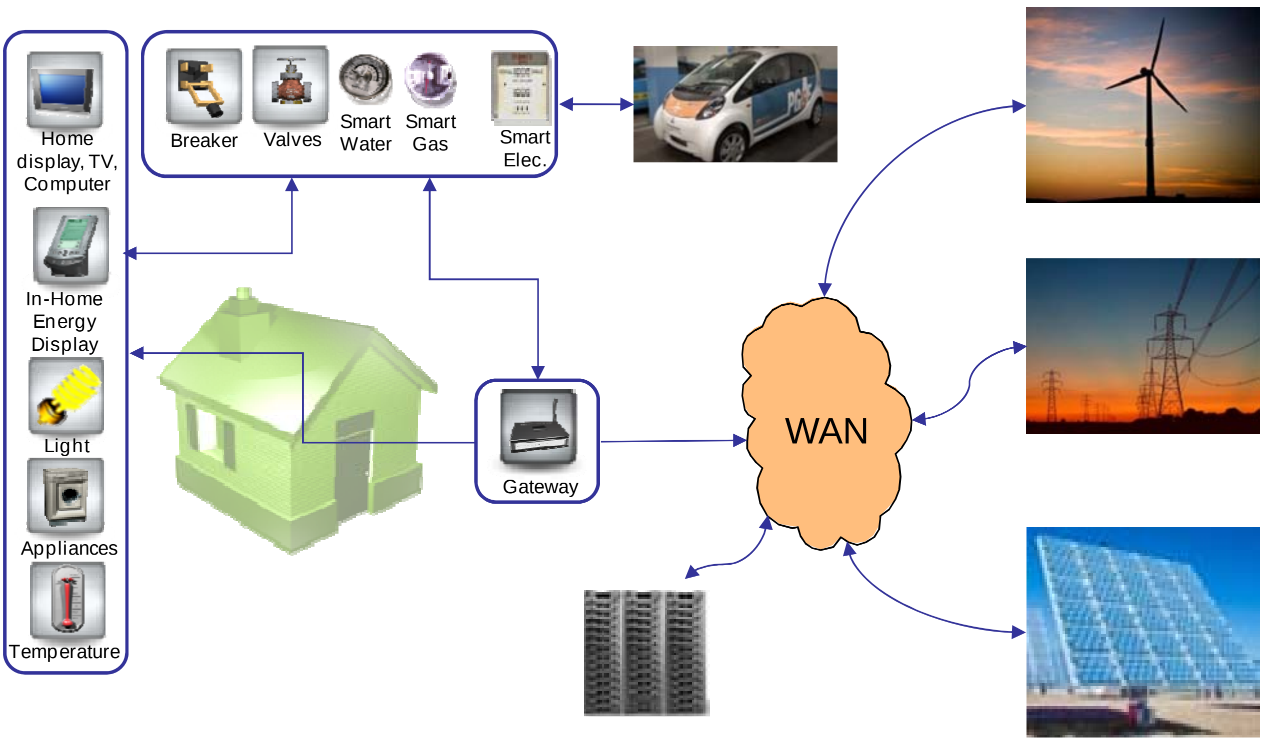

Figure B.1: Smart Metering Scenario

There are two broad categories of application use cases that will utilize the network illustrated in Figure B.1: end-to-end and peer-to-peer applications. The end-to-end applications are largely captured as the additional functionalities of the Smart Metering coordination group report to the EC [i.8] in Table B.1. As the communication requirements of these different functionalities often have a common core only those which offer additional complexity or payload have been included. The corresponding use cases are found in Smart Metering use case document [i.11].

Table B.1: Additional Functionalities of Smart Meters

Functionality	Description	Example
F1	Remote reading of the metrological registers and the designated market organisation	Clauses B.1.2 and B.1.7
F2	Two-way communication between the metering system and the designated market organisation	Clauses B.1.2, B.1.3, B.1.4 and B.1.5
F3	Meter supporting advanced tariffing and payment	As clause B.1.2
F4	Meter enabling remote connection/disconnection	As clause B.1.2
F5	Communication with individual devices within the home/building	Clause B.1.6
F6	Meter providing information via portal or gateway to an in-home/building display or auxiliary equipment	Clauses B.1.6 and B.1.7

In each of the scenarios which follow a single device is assumed. Although the payload will be common, a higher density of devices such as might be found in a dense urban environment will clearly impact the access to the medium. This is addressed in clause B.2 where the performance requirements are quantified.

The additional class of application involving peer-peer communication for scenarios such as electric vehicle charging or metropolitan networks are described in detail in TR 102 898 [i.9] and TR 103 055 [i.10].

B.1.2 Scenario 1: Obtain meter reading

The simplest scenario is where the Smart Meter reads and records the consumption and forwards this to the designated data centre. This may be a scheduled activity or at the request of the controlling device.

B.1.2.1 Communication characteristics

B.1.2.1.1 Basic

Under normal conditions the per device payload is light and not time sensitive.

B.1.2.1.2 Enhanced

In the case of a non-scheduled read of the data there may be a requirement for low latency, for distribution network management applications, such as overload or outage detection.

B.1.3 Scenario 2; Installation, Configuration and Maintenance of the Smart Meter

In this scenario the meter needs to be able to forward information on the network and supply quality as well as meter status and other non-metrological data. In turn the designated market organisation needs to be able to configure the meter at a distance and effect maintenance activities as well as software and firmware updates.

B.1.3.1 Communications characteristics

B.1.3.1.1 Basic

The normal configuration functions are a one off event and as such do not represent a significant communication load.

B.1.3.1.2 Enhanced

In the case of an upgrade to the software or firmware, although this will be an infrequent activity it is likely to present a significant communication load which should ideally be addressed within one access cycle of the wireless medium. This would be particularly important where cryptographic keys are updated.

B.1.4 Scenario 3; Monitor Power Quality

The complexity of the system to move electric energy from the point of production to the point of consumption combined with variations in weather, generation, demand and other factors provide many opportunities for the quality of the supply to be compromised. Electrical devices may malfunction, fail prematurely or not operate at all. Here the Smart Meter provides power quality data to the Distribution Network Operator, and/or Consumer who is able to use this data to monitor the Supply performance and if necessary instigate actions to ensure correct performance levels.

B.1.4.1 Communication characteristics

B.1.4.1.1 Basic

As per clause B.1.2.1.

B.1.4.1.2 Enhanced

Here there may be a requirement to support accurate and secure time synchronisation. M2M devices and M2M gateways may support time synchronisation or secure time synchronisation.

B.1.5 Scenario 4; Manage Outage Data

This scenario would cover the situation where there is a planned outage or unplanned outage of the network. The communication exchange is between the Smart Meter and the distribution network operator.

B.1.5.1 Communication characteristics

B.1.5.1.1 Basic

This would be an ad hoc low bandwidth requirement but one which is time sensitive. Hence low latency would be paramount.

B.1.5.1.2 Enhanced

When unscheduled there may be a requirement for the applications to execute within a tight time window which in turn would place further demands on the latency of response from the communications network and would be particularly demanding for battery powered devices.

B.1.6 Scenario 5; Demand Response Actions

Under this scenario either because of a planned maintenance activity on the network or owing to an unforeseen failure of the network, there will be an exchange of information between the Distribution Network Operator and the Smart Meter. There will in addition be a communication exchange between the Smart Meter and the consumer's display.

B.1.6.1 Communication characteristics

B.1.6.1.1 Basic

As for clause B.1.5.1.1.

B.1.6.1.2 Enhanced

As for clause B.1.5.1.2.

B.1.7 Scenario 6; Facilitated Distributed Power Generation

This scenario considers the specific situation for electricity where there may be distributed generating units such as solar units, wind turbines, micro-generators in the home etc. which pose specific problems for the attachment, control and disconnection of these devices to the electricity distribution network.

B.1.7.1 Communication characteristics

B.1.7.1.1 Basic

As for clause B.1.5.1.

B.1.7.1.2 Enhanced

As in the case of *Demand Response Actions* there may be a requirement to connect/disconnect devices from the network within a very narrow time window placing demands on the latency of any connection. In addition, as these devices may be collocated there will be a requirement for rapid coordination amongst peer devices.

B.1.8 Scenario 7: Electric Vehicle Charging

Three typical scenarios are considered:

- charging at the home;
- charging in an apartment complex;
- charging in a commercial complex.

For each of these there are corresponding minor charge cycle scenarios:

- short duration boost charge;
- medium duration half charge;
- long duration slow charge.

The residential case considers a lightly populated urban environment with a low density of electric vehicles. The charging of vehicles then assumes that the load can be accommodated by the distribution network without the need for coordination with other charging stations. However, in use cases where electric vehicle owners cluster their charging this may result in excessive transformer loading. Similarly, where fast chargers are deployed, this will further increase transformer loading; both of the alternative residential scenarios necessitate coordination amongst charging stations.

The apartment complex case is a medium-high density urban environment with a corresponding density of vehicles. The charging of vehicles is assumed to occur over the same period, most likely during off peak periods, overnight or at weekends, necessitating some coordination amongst the vehicles on charge to ensure that the distribution network capacity is not exceeded.

In the commercial complex case multiple simultaneous users need to be accommodated to ensure that an adequate charge of the vehicles is achieved in the time available which may vary from a short interval, say half an hour, to an eight hour charge. In contrast with the apartment scenario the commercial case will involve charging of vehicles during peak and off-peak periods.

The associated minor charge cycles cover a short duration 30 minute boost cycle to accommodate an anticipated need for a limited capacity charge to accommodate a round trip of, say, 25 km. The medium term charge may be required within two hours to permit a round trip of 40 km. In both of these cases the tariff will be of less consideration to the consumer who has a time sensitive need. The overnight slow charge would assure a full charge with a charge cycle optimised to use low tariff electricity.

B.1.8.1 Communication characteristics

B.1.8.1.1 Basic

Responsive, reliable, adaptive, low latency, secure communications with localized control are required. Reliability and responsiveness are key as the user cannot be trained to wait for his credentials to be authenticated/authorized. Low latency, adaptive communications with localised control are required for the real time negotiation and control of the distribution network by coordinating demand-response of multiple vehicle charging stations.

B.1.8.1.2 Extended

None yet identified.

B.1.9 Scenario 8; Metropolitan Mesh Networks

This scenario considers the connection of Smart Meters which may be located in areas with poor propagation characteristics, or do not have ready access to either a public wired or wireless network to the relevant utility network. This may arise because of the physical location of the meter:

- water meters in the ground;
- gas meters in a basement;

or because of the limited range of the device when battery powered. In these cases because of location or the availability of power, the transmission of data may only be achieved by multiple hops.

This mesh configuration also permits a communication architecture where each Smart Meter may act as a store and forward node for others connected to it. In such a configuration there may also be aggregation of traffic locally within the neighbourhood of key nodes before onward transmission of data to the WAN.

Where the isolation/remoteness of the meter is such that it would be uneconomic to provide a dedicated communications path to the WAN, then an intermediate hop may be provided by a suitably equipped utility vehicle which would itself act as a store and forward node, handing off its payload at the first convenient gateway to the WAN. Although in this particular case the data transfers would be limited to non-real-time applications, a timely exchange would be necessary to assure data validity.

In all cases given the potentially ad-hoc nature of the network connections these networks require mechanisms for easy formation and maintenance. The routing also needs to be flexible enough to adapt to the changing needs of the network and in particular the amount of data stored at each network node.

B.1.9.1 Communication characteristics

B.1.9.1.1 Basic

A robust self healing and configuring network with a range of 5 metres to 20 metres for indoor to outdoor communication and an outdoor line of sight range between 20 metres to 200 metres.

B.1.9.1.2 Enhanced

None yet identified

B.2 Smart Meter Service Requirements

This clause reflects the requirements of the scenarios in clause B.1 and makes use of available published data [i.15], [i.27] and [i.29] to give a working set of requirements against which the current SRD spectrum access rules can be assessed. The service requirements identified cover many aspects of performance, however, the focus here will be on those requirements which are key in determining the daily traffic loads. These are:

- the frequency with which metrology data is read;
- the number of times this data is uploaded to the central collection point.

For a typical 95 % probability of a reception, each data packet has to be transmitted at least twice within this maximum update period [i.16]. The mandatory update periods are summarised in Table B.2.

Table B.2: Intervals of transmission for different applications and metering media

	Mandatory billing and visualisation		Informative aspects (consumer)
Meter Type	**Average Send interval Max (min)**	**Visualisation interval for energy provider (h)**	**Visualisation interval for consumer (min)**
Electricity	7,5	1	15
Gas	30,0	1	60
District Heating	30	1	60
Hot Water	240	24	-
Heat cost allocators	240	24	-
Heat/cold (sub-metering)	240	24	0
Repeater	240	-	-

For billing purposes and to minimise repeated collisions, the individual transmission interval varies from ±1 % up to ±20 % from the average interval.

B.3 Smart Meter Performance Requirements

B.3.1 Introduction

The application of low power, low duty cycle techniques to Smart Metering communications requirements leads to considerations of several potential device deployment topologies. Devices may be located in a variety of sites from inside buildings to exterior walls, below ground or free-standing locations.

The typical application scenarios discussed in clause B.1 and the Service Requirements of clause B.2 indicate the need for device-to-device communications in order to meet the needs of device connectivity required for practical Smart Metering applications. See annex C for a fuller discussion of the network topology and interface considerations.

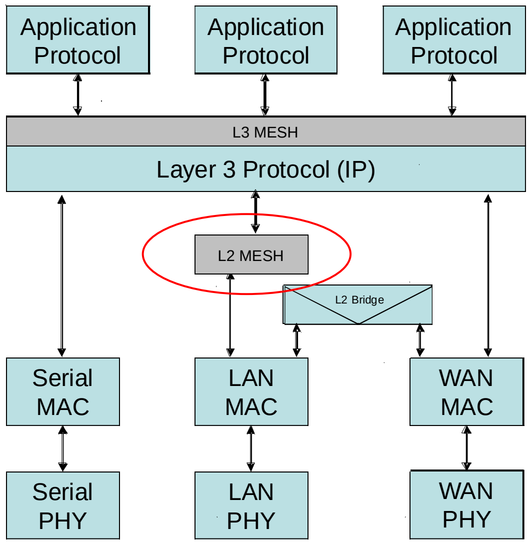

Figure B.2: Multi-hop Protocol Stack

In this analysis, we consider a MAC Layer multi-hop protocol, as shown in Figure B.2, and how that protocol may operate in a manner consistent with the low duty cycle access techniques used for SRDs. A multi-hop protocol above the Network Layer would be similar, but possibly with higher associated latency and overhead.

B.3.2 Deployment Model

Figure B.3 shows the use of inter-connected Gateways and their connection to a WAN.

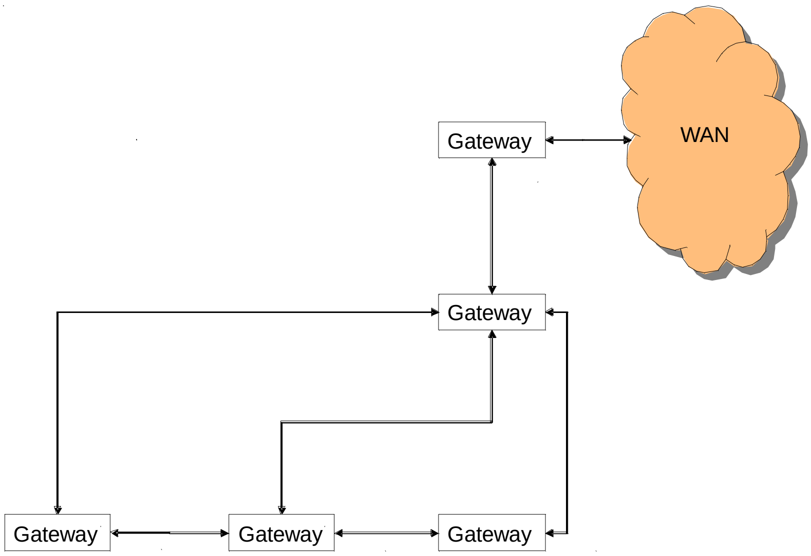

Figure B.3: Gateway MESH + Gateway-WAN AP

A Gateway serves as the network point of attachment for a Node which corresponds to a Smart Meter. The Gateway also serves to route traffic from the WAN to the HAN devices associated with the Smart Meter.

In general, any device could have a WAN link but considerations of economic factors may lead to a significant ratio of nodes to APs. The number of nodes per AP is important for both cost and performance reasons. Larger node populations provide more diverse paths to the AP, the provision and operation costs of which are spread over the nodes supported.

All application traffic for the nodes supported by an AP needs to pass through the AP as well as acknowledgments for traffic from the nodes to the AP.

Management traffic to support the multi-hop routing of packets from the nodes to the AP will be in addition to the application traffic.

B.3.3 Access mechanism

In the following analysis we assume that all devices accessing the medium operate under low duty cycle regulations. For systems of the same type, the analysis holds for determining the throughput of the channel versus offered load i.e. simultaneous transmissions would constitute mutual interference. For unlike systems, simultaneous transmissions would amount to interference but we assume that the effect of this interference is similar to collisions for like systems.

The current regulations on SRDs permit access to the permitted frequency bands without centralised control. EN 300 220 [i.18] defines Duty Cycle limits for different sub-bands. The permitted Duty Cycle limit may depend upon use of a Listen Before Talk (LBT) interference mitigation technique. Here we consider whether this adaptation of the permitted Duty Cycle is relevant to Smart Metering applications and begin our analysis by considering Aloha.

B.3.3.1 Aloha

Aloha, the simplest form of random uncoordinated channel access mechanism, allows any packet that is available for transmission to be sent on the medium with successful packet reception reported via an acknowledgement. In the absence of an acknowledgement, the transmission is repeated.

In pure Aloha, the probability of successful packet transmission of fixed length packets of duration [m] is:

- probability that no other packet is transmitted in the interval $2m$.

In other words, in its simplest form, Aloha assumes all non-collided packets are successfully delivered.

The classical expression of pure Aloha throughput [S] is:

$$S = Ge^{-2G}$$

Where [G] is the total number of transmission attempts including retransmissions that fall in the duration m. [S] is normalized since the unit interval is the fixed length packet duration and so [S] is also the Aloha efficiency.

The number of transmission attempts obviously depends on the number of active nodes and the probability with which each node generates a packet. In the classical Aloha analysis, inter-arrival is a Poisson distribution as each transmission is assumed to be uncorrelated with any other.

For this simplistic analysis we equate [G] to the average Duty Cycle of the link being shared by the nodes i.e. the Duty Cycle gives us a measure of the number of packets generated in a given time interval.

Figure B.4 is the familiar 18 % maximum efficiency figure of the basic Aloha analysis.

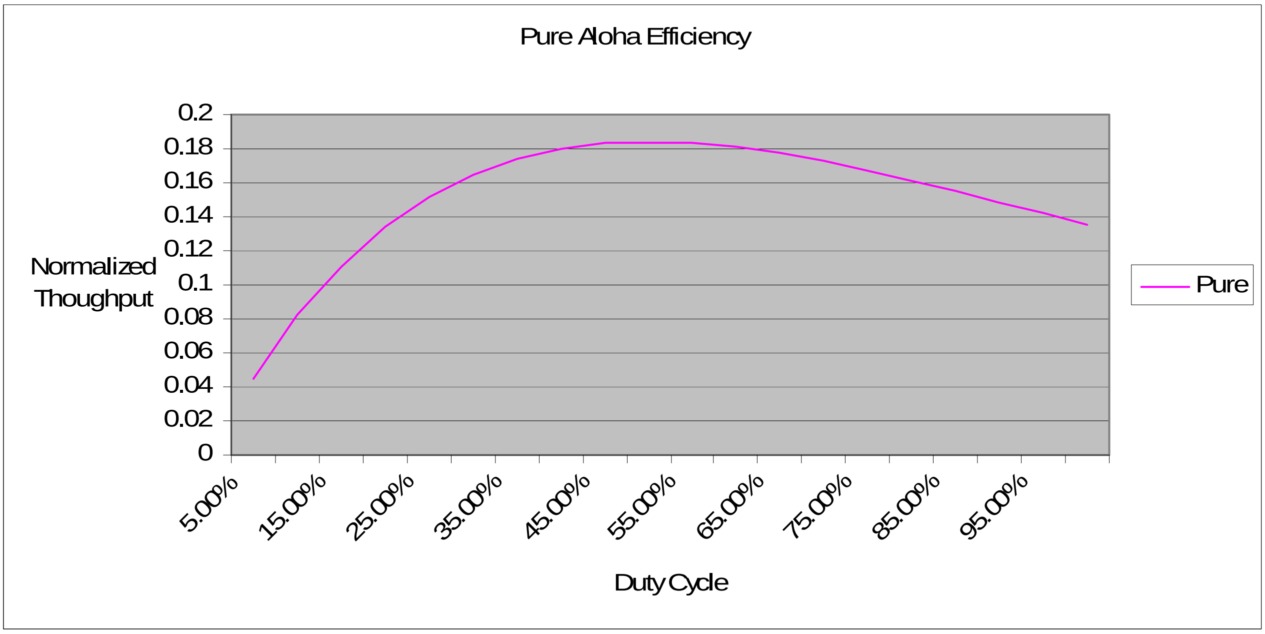

Figure B.4: Pure Aloha Throughput

B.3.3.2 Slotted Aloha

A simple form of coordination can be introduced using slotted Aloha. By synchronising the transmitters to slotted fixed length time intervals (equal to the packet duration), the collision window is reduced to the interval of a single packet duration.

Again using the Duty Cycle as a measure of offered load we can plot the Slotted and Pure Aloha curves, see Figure B.5.

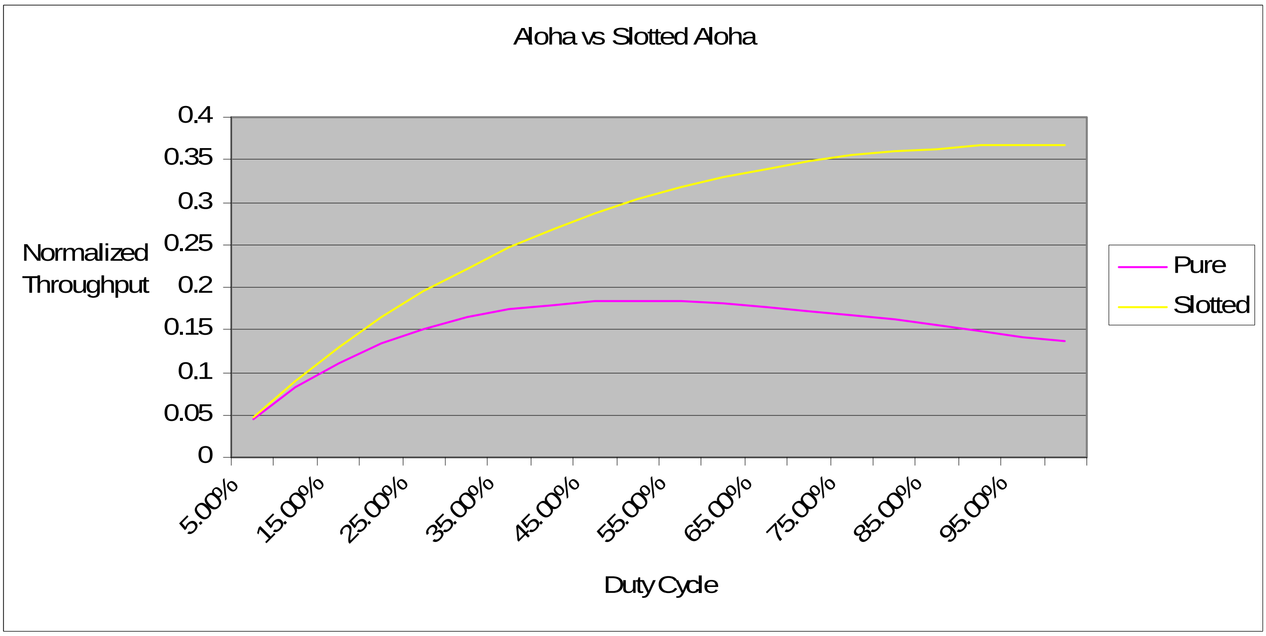

Figure B.5: Slotted and Pure Aloha Throughput

B.3.3.3 Listen Before Talk

Clear Channel Assessment (CCA) is used to avoid collisions by sensing the medium before transmission. If the medium is occupied the transmitter defers with some randomised delay before re-attempting its transmission operation by once more sensing the medium. CCA is the sensing mechanism of LBT which is used in Carrier Sense Multiple Access (CSMA) algorithms.

For an equivalent payload and data rate, the throughput of a CSMA Collision Avoidance (CA) mechanism is much greater than Aloha as the load approaches the channel capacity or the Duty Cycle approaches 100 %. Under extreme traffic load conditions a collision detection or low duty cycle limit may be required to assure equity of channel access and sharing. However, as we are considering only low traffic loads these techniques will not be analysed here. A comparison of throughput versus transmission attempts can be found in the literature [i.17]; a summary is shown graphically in Figure B.6 showing the normalized throughput versus load curves for a variety of standard carrier sense channel access mechanisms as well as the Aloha curves.

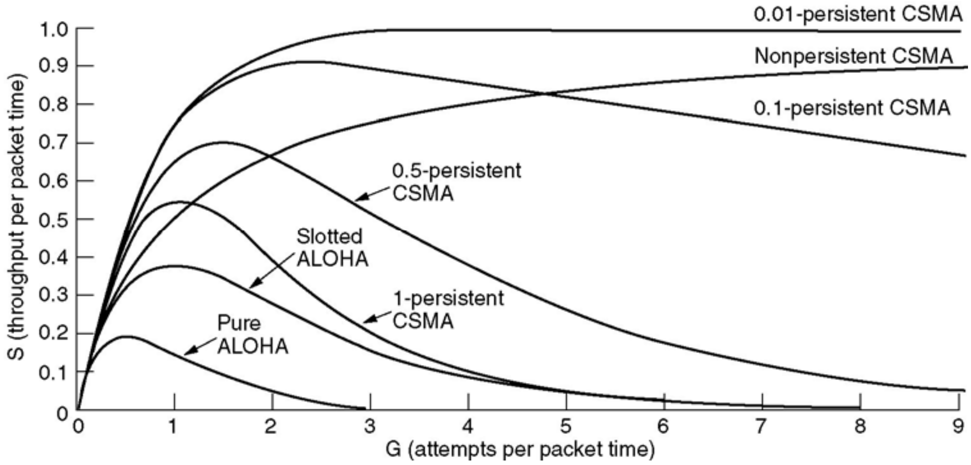

Figure B.6: Comparison of Aloha and Carrier Sense mechanisms

Figure B.6 shows the comparative performance for a range of CSMA/CA algorithms and the two Aloha variants and, as can be seen, at low offered loads the performance of all channel access mechanisms converge. Furthermore if we examine the performance curves for Pure and Slotted Aloha it can be seen that they begin to diverge significantly only at offered loads of approximately 10 %, as shown in Figure B.7. So for offered loads below this we can restrict our analysis to the simplest multiple access scheme of Aloha.

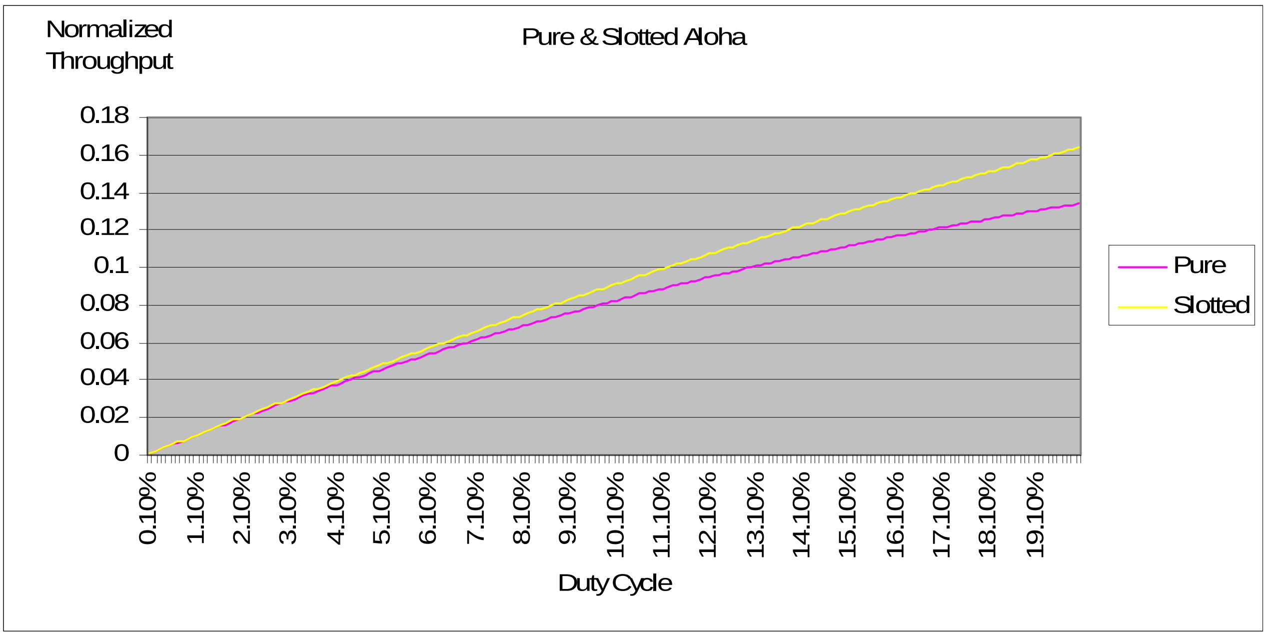

Figure B.7: Low Duty Cycle Detail

From this we can conclude that at loads of less than 10 %, CSMA/CA offers no improvement over either of the two Aloha access mechanisms. Of these two mechanisms, at duty cycles of up to 10 % there is no significant difference between throughput for a given offered load suggesting that for simplicity for the target SRD Duty Cycle values of a few %, pure Aloha is a suitable channel access mechanism for Smart Metering applications.

B.3.3.4 Closing Remarks on Aloha and CSMA

Throughout this analysis we have assumed that low duty cycle and hence low traffic loads prevail. Under these conditions the rate of arrival of packets does not exceed the channel capacity. However, as is shown in Figure B.6, if the number of packets to be carried on the medium exceeds the channel capacity either because of an increased rate of generation from existing users or because of the addition of further users who wish to use the channel, the throughput of the systems falls as collisions increase.

The throughput increases with the choice of collision avoidance which would complement any clear channel access assessment. Ultimately the selected access mechanism should be tailored to the expected traffic loads and should be informed by the work in CEPT SE24 WI 23 and ETSI STF 411 which are respectively considering Improving Spectrum Efficiency in SRD Bands and Low Duty Cycle as a mitigation technique for SRDs.

B.3.4 Traffic Model

A model was generated to calculate the duty cycle of APs and Nodes in a MESH network to determine whether SRD medium access rules would support Smart Metering applications. The model is described and included in annex D. The model is used to analyse the number of nodes that may be supported by an AP under certain transmission assumptions of data rate and probability of transmission success. The following clauses describe the assumptions used and sample output from the model.

The main traffic of concern for Smart Metering is the reading of meters and the delivery of information to HAN devices for interaction with the consumer. In addition, Network Management traffic needs to be estimated for the global network (NM) and local MESH (L2) network operation.

In this analysis, it is assumed that:

- One Smart Meter is associated with one node and all Smart Meters are equivalent.
- Smart Meters transmit their reading information at random intervals and are uncoordinated with any other Smart Meter transmission.
- HAN traffic is delivered to the HAN devices via the gateway.
- General Network Management traffic is carried in IP packets.
- End-End traffic is carried in IP packets and the associated overhead is included.
- Local multi-hop management traffic is MAC Layer i.e. no IP overhead.

Meter reading rates and packet sizes are estimated for a nominal Smart Metering deployment.

Communications are assumed to use Aloha as the channel access mechanism and to be acknowledged (for re-transmission decisions by the source nodes). Packets originate at the nodes for Smart Metering applications i.e. traffic generation is from some activities scheduled by the meters or associated applications in the gateway. Acknowledgements are generated by the WAN AP. HAN traffic is assumed to originate from the WAN side of the AP and to be transmitted via the MESH to the target node.

Constants in the model define the rate at which packets are generated and enable the total number of packets per day to be computed for each category of traffic. The model estimates traffic for each of these categories using data sizes and transmission frequencies defined as constants at the beginning of the model. The Duty Cycle is computed from the sum of the traffic categories. See the model and its description in annex D for details.

B.3.5 Multi-hop (MESH) Considerations

Most analysis of mesh radio systems in the literature deal with high traffic cases, for instance to provide the last mile internet connection. The system here is a low traffic case, where the purpose of the MESH is to provide robust connectivity and reduce the number of APs rather than to transfer large amounts of data.

For a Smart Metering MESH, there will a complex interaction between power, data rate, duty cycle, proportion of battery powered devices, density of nodes to APs. The latter two are subject to deployment factors and will vary from place to place and over time.

Traffic from outlying nodes is delivered to the AP by repeat transmissions from neighbouring nodes. MESH protocols are complex to model, with some traffic being re-transmitted over several hops and other traffic being delivered directly to its destination. Determining the optimum parameter set for these transactions continues and we have made some simplifying assumptions for our model. In our simplified model, the effects of multi-hop traffic delivery are modelled as a lumped parameter which is a ratio of nodes acting as forwarders to nodes served by the AP e.g. some fraction of the total traffic is repeated and hence appears as additional load in the duty cycle computation.

In addition to the repeated traffic, there is a management overhead associated with the MESH of nodes. Nodes need to identify paths to the AP and explore and maintain their communications links within their immediate radio neighbourhood.

B.3.6 AP Duty Cycle Estimate

The Duty Cycle calculations shown in the following plots use the deployment parameters of Table B.3 which are consistent with the Service Requirements of clause B.2. The meter sampling interval and number of meter channels per sample determine the total meter data per day. The number of uploads determines the interval between transmissions to the back office applications and hence the packet size of these events. $P_{success}$, explained in Transmission Reliability below, models re-transmitted packets. Forwarding determines, as explained in Multi-hop (MESH) Considerations above, the MESH hop traffic overhead. The number of neighbours affects the traffic generated to maintain the MESH.

Table B.3: Deployment Parameters

Meter Sampling Interval	7,5 minutes
Number of Channels per Sample	2
Number of Reading Uploads per day	6
$P_{success}$	70 %
Forwarding	80 %
Number of MESH neighbours	20

The traffic generated at the AP for meter reading (AMR - Advanced Meter Reading) and HAN devices, together with AP network management traffic is plotted in Figure B.8 as a duty cycle averaged over a day for various populations of nodes per AP. The plot is repeated for different data rates.

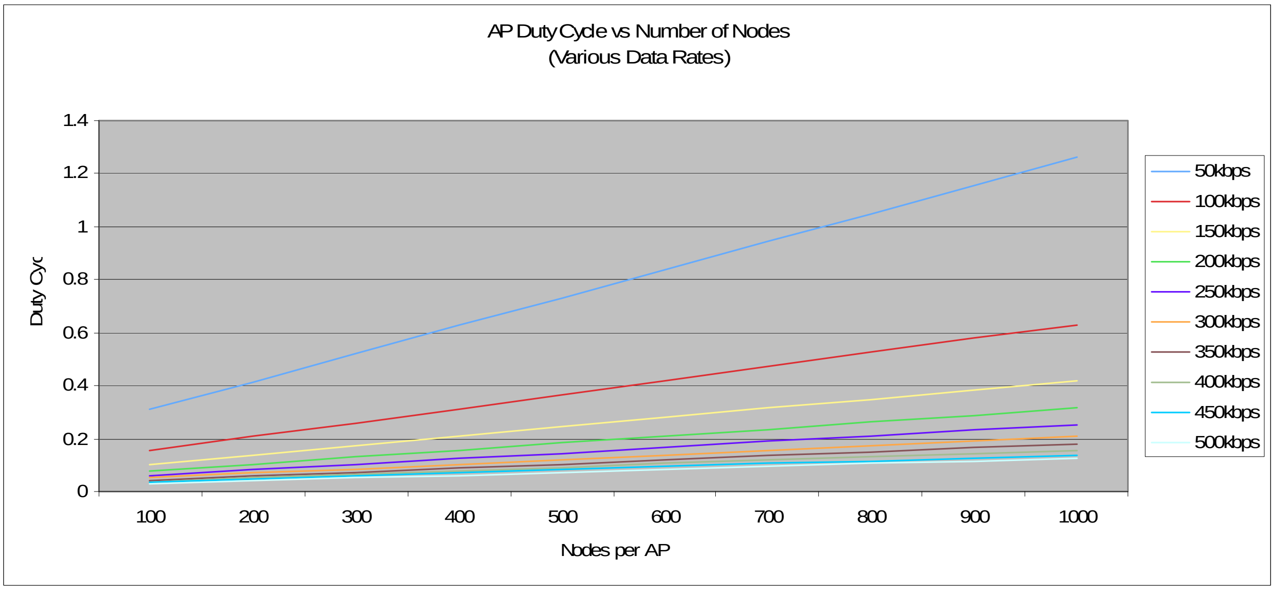

Figure B.8: AP Duty Cycle for NM + AMR + HAN

The plot shows that for data rates above 100 kbps more than 900 nodes can be supported at a duty cycle less than 1 %.

B.3.7 Node Duty Cycle Estimate

The corresponding plot for each node shows a higher duty cycle owing to the repeated traffic over the MESH. Figure B.9 indicates that for a duty cycle of 1 % approximately 300 nodes per AP can be supported for data rates over 100 kbps.

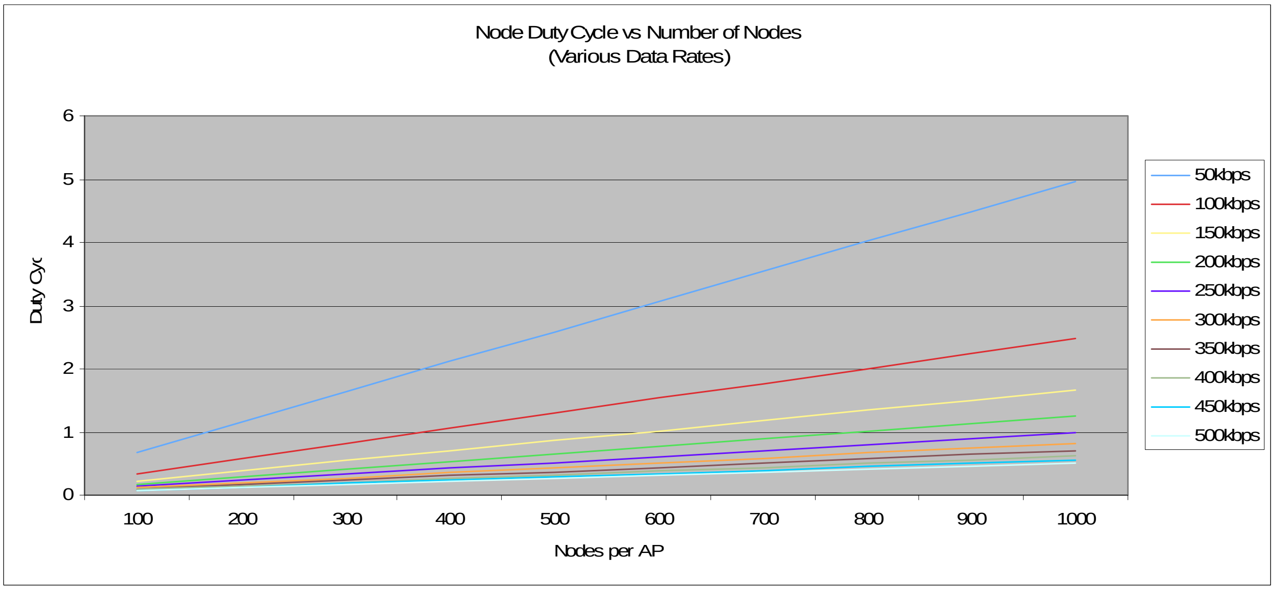

Figure B.9: Node Duty Cycle for NM + AMR + HAN

B.3.8 Transmission Reliability

The probability of success parameter [$P_{success}$] is another lumped parameter in the model. It is used to generate an estimate of the re-transmitted traffic i.e. repeated transmissions from the source that were not acknowledged by the AP. Re-transmissions are applied to all traffic including the forwarded traffic.

$P_{success}$ represents effects dependent on several different parameters including:

- Transmit power which determines the link margin of the received signal for a given propagation environment.
- Probability of collision of simultaneous transmissions by neighbouring nodes. This is, in turn, dependent on the number of available channels since the node population can be partitioned, or may use AFA techniques, over multiple channels to reduce the effective number of neighbours.
- Data rate which determines the on air duration for a given packet size and hence affects the probability of collision for Aloha channel access.

The following plots indicate the effect of the $P_{success}$ value on duty cycle for this model.

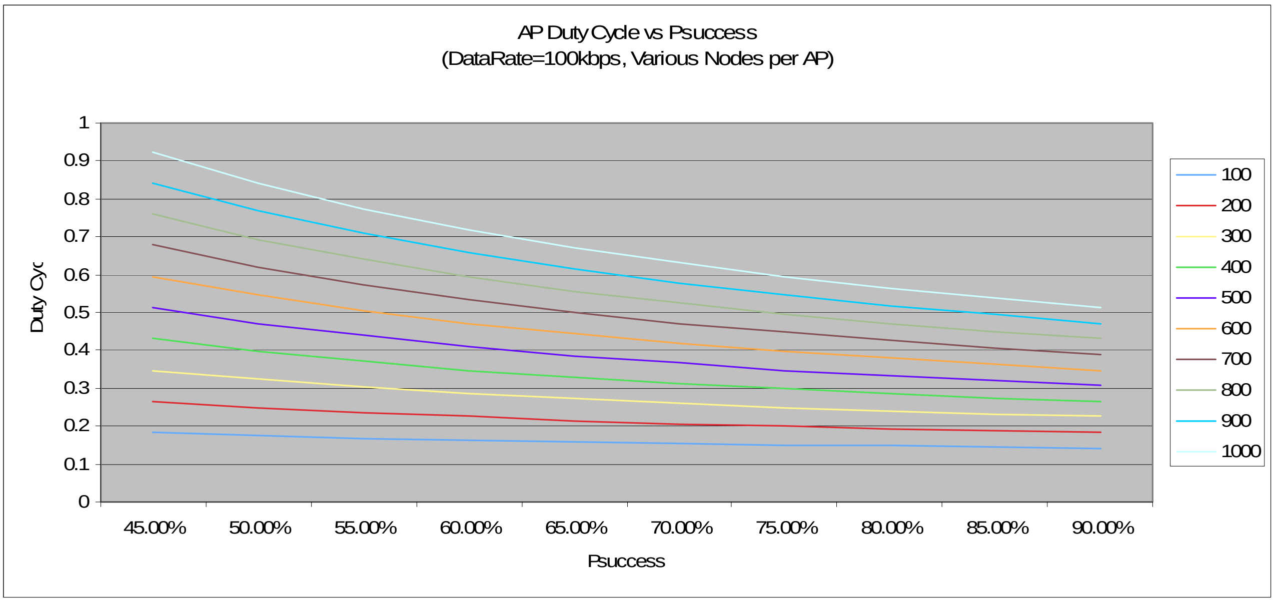

Figure B.10: AP Duty Cycle vs $P_{success}$

Figure B.10 shows the effect on AP duty cycle of varying $P_{success}$ for various node populations using 100 kbps data rate. In the model the effect is principally to vary the load due to re-transmissions. The AP capacity for supported nodes increases by approximately 50 % for a given duty cycle over a $P_{success}$ range from 60 % to 90 %.

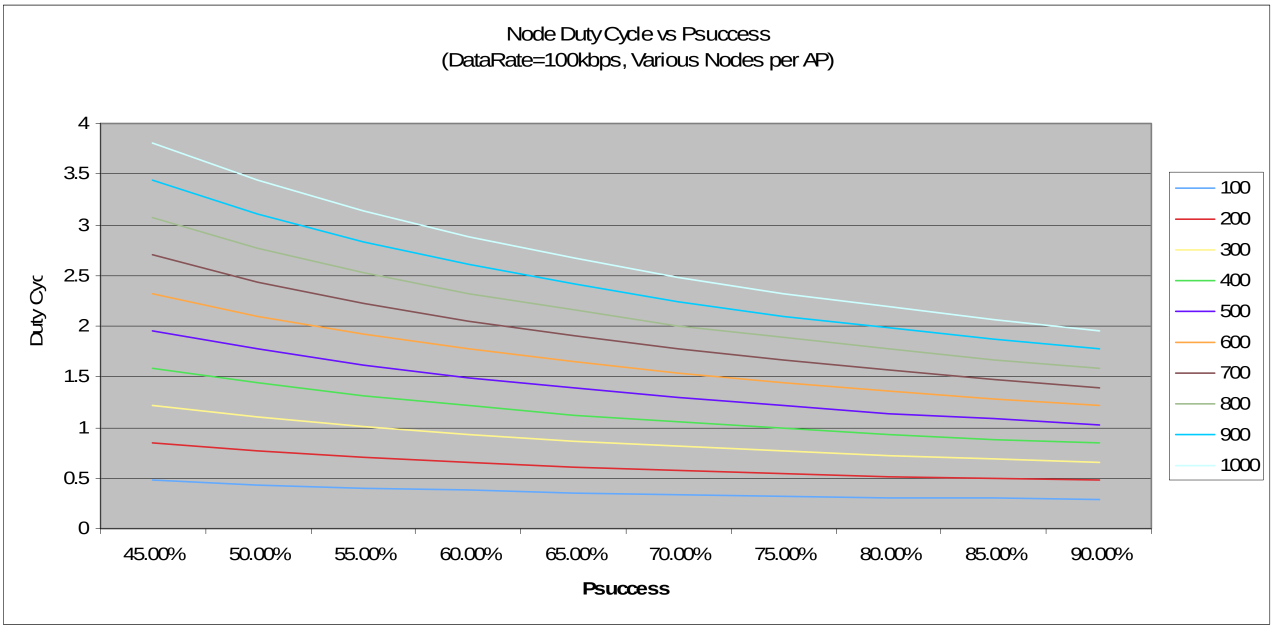

Figure B.11: Average Node Duty Cycle vs $P_{success}$

Figure B.11 shows the equivalent increase in node population versus $P_{success}$. The effects of lower re-transmission rates for the forwarded traffic over the MESH is again the main benefit as $P_{success}$ increases.

B.3.9 Traffic model conclusions

This preliminary analysis of Smart Metering data traffic between a WAN and a MESH of nodes shows:

- Low duty cycle spectrum access techniques may support Smart Metering applications for data rates above approximately 100 kbps.
- Low duty cycle operation for an AP (Figure B.10) is possible for a MESH up to approximately 1 000 nodes per AP and a $P_{success}$ of approximately 70 %.
- Average node duty cycles, including forwarding traffic, is consistent with low duty cycle operation for approximately 300 nodes per AP under the same conditions (Figure B.11).
- Increasing $P_{success}$ provides proportional increases in node population per AP. $P_{success}$ may be improved by higher transmit power as well as a larger number of channels and other factors.
- SRD type access rules can be applied to Smart Metering deployments provided sufficient link margin is available for the node-node links necessary to provide the MESH forwarding from nodes to the shared AP.
- A channelisation approach consistent with 100 kbps data rates for low complexity modulation schemes should be considered.
- Sufficient channels are needed to limit collisions of simultaneous, uncoordinated transmissions.

B.4 Smart Metering Radio Frequency Parameters

B.4.1 Introduction

B.4.1.1 Scenario

A typical scenario for the deployment of meters in the home is shown in Figure B.12 which uses an apartment complex and single dwelling occupancy to represent the possible topologies.

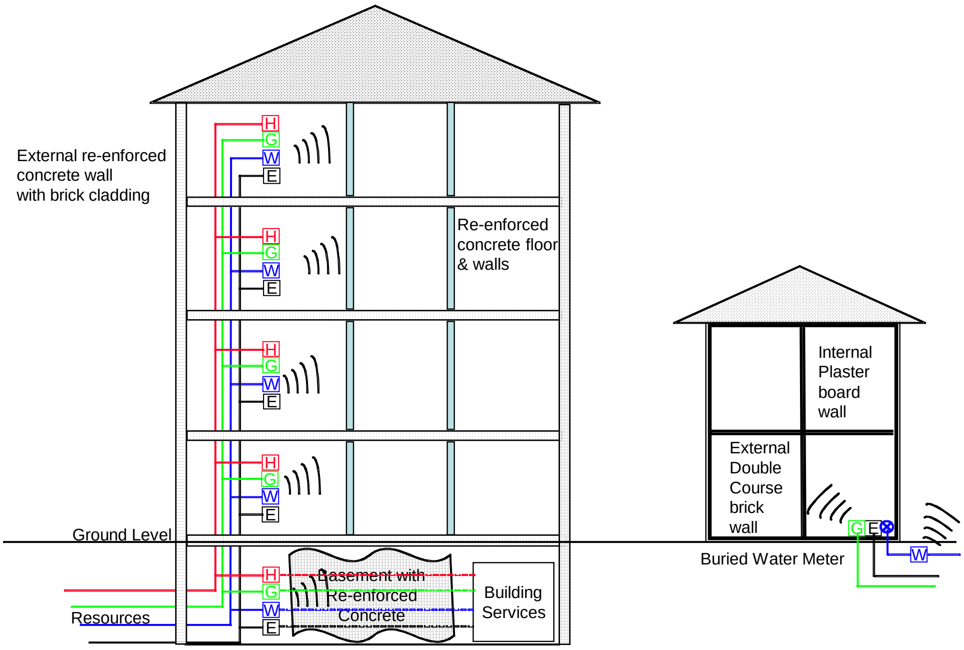

Figure B.12: Meter Deployment in the Home

From Figure B.12 it may be seen that there are a number of key considerations which drive the RF performance parameters:

- Meter location in the building.
- Construction of the building.
- The communications power supply.

B.4.1.2 Meter Location in the building

The location of meters marks the boundary between the service provider and the customer/consumer. The location is a compromise between ease of installation, serviceability, local installation building practices and the principal device consuming the resource.

Building services such as central heating, water heating and ventilation systems are likely to be located on the lowest level of the building which will often be the basement. Where this is the case resources such as water, gas and electricity may be terminated adjacent to the building services plant.

Where no basement is present, or in a multi-occupancy building where each occupant is responsible for the resources consumed, the meter may be at ground level or adjacent to the dwelling entrance.

B.4.1.3 Construction of the building

The construction of the building and in particular the attenuation of the materials used, will play a significant role in determining the deployment parameter. These include the:

- RF power required to assure the coverage necessary (at the specified link margin);
- minimum number of hops from meter to access point;
- density of access points (and hence the operating costs).

The expected range requirements are:

- 5 metres to 20 metres for indoor to outdoor;
- 20 metres to 200 metres outdoor line of sight.

Two types of construction are considered:

- double course brick/agglomerate found in many single occupancy dwellings;
- re-enforced concrete with cosmetic facing, the typical construction of multi-dwelling buildings.

In both cases the relevant attenuation figures are drawn from independent studies [i.24], [i.38] and [i.39].

B.4.1.4 The Communications Power Supply

It can be expected that while electrical power will be available in all locations, in some instances it may be neither practical nor economical to power a meter from an external source. In such instances power for the transmission of data will be provided by battery or an equivalent limited source. Limited power sources will influence communication protocol design but not RF communication parameters.

In general battery powered devices although contributing to MESH traffic, would not be expected to forward it. This together with other power conservation techniques, may increase the number of hops to reach an access point. Consequently, the total traffic may increase which may in turn affect the active duty cycle of the network.

The proportion of battery powered devices is recognised as a key design consideration in the deployment of any system if duty cycle and traffic loads are to be constrained.

B.4.2 Transmit Power

Based on the scenarios in clauses B.1 and B.4.1.1, the necessary maximum permitted radiated power should be at least 100 mW e.r.p. This will permit:

- a typical operational range of 20 metres to 200 metres (57 dB to 77 dB free space attenuation);
- propagation through 2 walls to 4 walls (assuming 5 dB brick and 15 dB reinforced concrete) with penetration losses of:
  - best case - 10 dB (2 brick walls);
  - worst case - 60 dB (4 concrete walls).
- indoor to outdoor transmission between two facilities;
- fading margins necessary for link stability.

Table B.4 lists the relevant parameters defined by the scenarios and their values derived from the literature.

Table B.4: Path loss and scenario parameters for 868 MHz ISM Band communication

Parameter	best	Typical	worst	References
attenuation factor *(n)*	2 (free space LOS)		4 (obstructed environment)	[i.35] and [i.37]
attenuation brick wall att_bw		5 dB (23 cm)		[i.38] and [i.39]
attenuation concrete wall att_cw		15 dB (25 cm double layer reinforced concrete wall with 20 cm grid size)		[i.38] and [i.39]
fading margin X_sigma (Gaussian distribution with variance sigma)	10 dB	18 dB	20 dB	[i.35] and [i.41]
receiver sensitivity		Receiver Sensitivity (state-of-the-art industrial example): BPSK @ 20 kbps: -110 dBm O-QPSK @ 100 kbps: -101 dBm O-QPSK @ 250 kbps: -100 dBm		[i.40]
number of walls indoor	0		4	scenario
number of walls inter-facility	2		4	scenario

In the case of the 868 MHz ISM band communication the path loss is calculated as [i.35].

$$PL\ (d) = 31{,}52\ \text{dB} + 10\ n \log (d) + \text{X\_Sigma} + \text{wall attenuation}.$$

The term X-Sigma was derived from empirical work [i.36] and [i.41] and considers dynamic propagation conditions reported in the literature, not only spatial on site variations but also link impairments due to people or object movement within the radio coverage area [i.36].

Using the information provided, in Table B.4 the total link budget under free space LOS conditions ranges between:

- a best case of $31{,}52 + 10 \times 2 \times \log (20) + 10 + (2 \times 5)$

  $= 31{,}52 + 26 + 10 + 10 \approx 77$ dB

- and a worst case of $31{,}52 + 10 \times 2 \times \log (200) + 20 + (4 \times 15)$

  $= 31{,}52 + 46 + 20 + 60 \approx 157$ dB

If a transmit power of 20 dBm is assumed together with a receiver sensitivity of -105 dBm [i.40], a link budget of 125 dB is available. This would not satisfy the worst case (157 dB), but would allow transmission through 2 reinforced concrete walls (the minimum for inter-facility communication) and 200 m free space with a common fading margin.

$$[31{,}52 + 46 + (2 \times 15) + 18 \approx 125\ \text{dB}]$$

Therefore to enable the operation of Smart Meters in the deployment scenarios described above, which are assumed representative for Central European building construction practices, will require a maximum transmit power of not less than 100 mW e.r.p.

The wide range of best to worst case link budget may permit useful system gains from the exploitation of Transmit Power Control (TPC) whilst at the same time minimising inter and intra-system interference potential.

B.4.3 Data Rate and Modulation

The Smart Meter performance requirements B.3 show that a data rate of 100 kbps is required to support the application scenarios identified in clause B.1 and the service requirements identified in clause B.2. Narrowband modulation techniques will permit this data rate in an occupied bandwidth of 150 kHz.

Where higher data rates are necessary or for applications where frequency drift might be expected owing to extended operational temperature requirements adjacent channel bonding would allow accommodate any increased bandwidth requirements. For example see [i.22].

Both these scenarios are consistent with a channelisation scheme of 200 kHz found in E-GSM-R.

B.4.4 Interference Mitigation

A number of factors provide inherent interference mitigation:

- Building materials will offer attenuation between 5 dB and 26 dB [i.24].
- Meters located in basement or other poor propagation environments e.g. buried water meters.
- Battery operated devices will be active for a minimum period consistent with operational needs in order to conserve power.

Other techniques for example transmit power control (TPC) may be used to provide further mitigation against interference.

B.4.5 Duty Cycle

B.4.5.1 Node Duty Cycle

The traffic analysis for the simplified MESH network described in clause B.3 shows that, for the nominal parameters used in the computation, an AP can support up to approximately 1 000 nodes while staying within nominal 1 % Duty Cycle.

However, since MESH nodes re-transmit near-neighbour traffic en-route to the AP, the corresponding node population for the AP 1 % Duty Cycle is approximately 300.

To contain the operational costs the ratio of simple MESH nodes to complex APs should be as high as possible.

Raising the duty cycle to 2,5 % allows 1 000 MESH nodes to be supported by a single AP as shown in Figure B.9. A duty cycle of 2,5 % is also consistent with the results of the Kolberg test which evaluated the interference between SRDs and E-GSM-R in its designated 873 MHz to to 876 MHz [i.25].

B.4.5.2 Normal and Event Driven Traffic

Observations from current Smart Metering deployments indicate that for normal the average node active ratio is well within the limits of 2,5 % or 1 %. The meter reading data is uploaded to the central applications relatively infrequently and for a significant majority of time the devices are inactive. Since the nodes are rarely active the traffic model assumes that the traffic generation is uncoordinated.

However, Smart Metering applications include functions such as indication of outage and other event response traffic. In these cases, since a number of nodes will detect the event simultaneously and, even with a random delay before transmission, the resulting traffic is unlikely to be spread in time as is expected for uncoordinated traffic. The event response traffic will be transient in nature and will be presented as a peak in the traffic load.

Since outage and other event responses are very important classes of Smart Metering data, and that these are transient in nature, it is recommended that the duty cycle limit, consistent with co-existence requirements be measured over a specified interval without peak limit in any sub-interval.

Annex C: Communications Architecture

C.1 Smart Meter Topologies

In response to EC Mandate 441 [i.1] on Smart Metering, communications within a Smart Meter domain is described in terms of non-electricity meters, electricity meters, a home automation sub-domain and a gateway to a centralized control application via a wide area network. This is illustrated in Figure C.1:

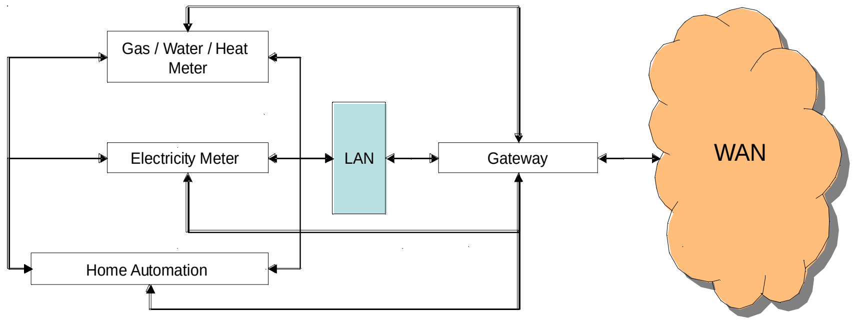

Figure C.1: M/441 Smart Metering Domain

Figure C.1 shows that there are a number of interfaces implied in this view of the SM architecture:

- Non-electricity meter - LAN.
- Electricity meter - LAN.
- Home automation sub-domain - LAN.
- LAN - Gateway.
- Gateway - WAN.

In addition, the LAN may be bypassed to allow direct interfacing to the gateway.

The communications protocols that may be invoked to support these exchanges are shown in Figure C.2 Home Automation and meter equipment can exchange packets over a LAN MAC/PHY or via a serial (or other) device-device link, possibly with daisy chain for multiple device extensions.

The LAN MAC/PHY could be provided via any suitable LAN specification, including published standards and industry specifications.

The path to the gateway could be via the LAN MAC/PHY or again directly via the serial (or other) link.

The gateway may act as a L2 Bridge (MAC Layer Bridge) to link the serial/LAN MAC to the WAN MAC if such an interface exists. Alternately, L3 Routing can pass packets between the local and wide area network domains. A suitable L3 protocol would be IP (either v4 or v6).

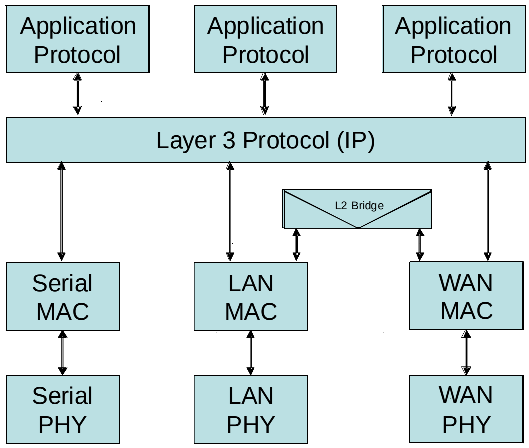

Figure C.2: Layered M/441 Communications

The meter communications illustrated in Figure C.2 may be constructed in several ways:

- Integrated with the meter.
- Co-located with the meter with an internal bus.
- External to the meter with an exposed bus.

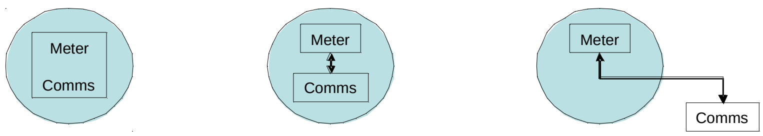

Figure C.3: Meter Communications Alternatives

Figure C.3 shows the three different means of communication attachment to the metering unit. The internal and external buses shown are transparent to the communications architecture being considered here. In other words, the three potential methods of attachment are considered to be equivalent for the purposes of the present document.

The view expressed in Figure C.1 is one possible way of deploying meter communications. The centralized application accesses the meter communications unit via the gateway attached to the WAN. Each meter communications unit is associated with a gateway.

An alternative deployment may include meter communications units which are not associated with a WAN gateway and require their communications to be routed via intermediate devices between the gateway and the meter communications unit. These intermediate devices may be Smart Meters themselves or forwarding devices. The forwarding devices may be dedicated to the forwarding function or be a part of some other function.

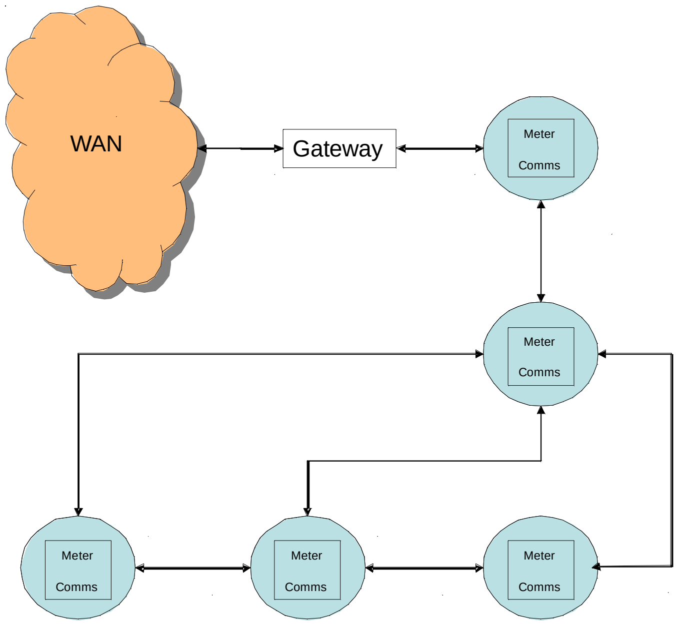

Figure C.4: Mixed Meter Communications

Figure C.4 shows such a deployment where meter communications units provide various paths between themselves, dependent on the radio path and operating state, with one of the meter communications units providing connection to the gateway.

In this deployment, an additional interface is introduced:

- Meter communications unit - meter communications unit.

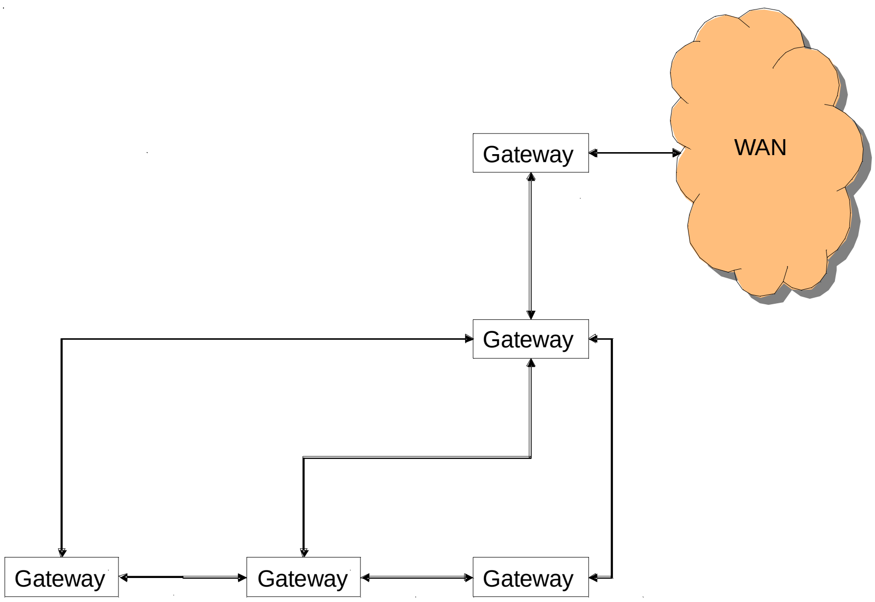

Figure C.5: Gateway - Gateway Communications

Figure C.5 shows a possible deployment where the gateways themselves form a multi-hop path to the WAN i.e. some gateways are connected to the WAN and some are not. Packets pass via intermediate devices to reach a gateway serving a specific meter communications unit.

As for the previous example, the intermediate devices could be gateways or any other device providing forwarding services to the gateways.

The communications protocol added to support this case is a multi-hop or MESH protocol which could reside either at L2 or L3 as shown in figure C.6. The MESH sub-layer could apply to the device or the gateway entities.

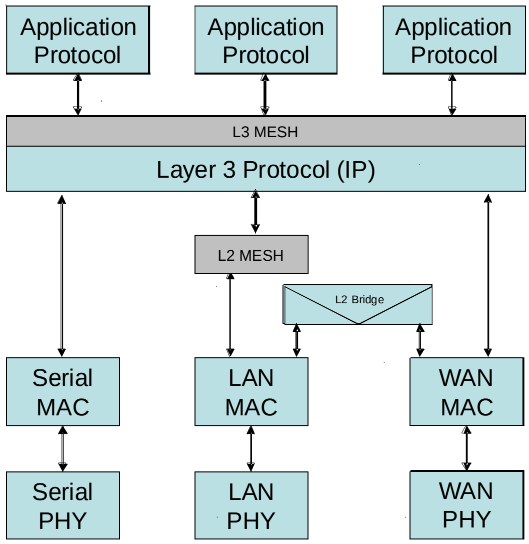

Figure C.6: MESH Sub-Layer Communications

C.2 Interfaces

Although the present document is primarily concerned with the interface between the gateway and the WAN and the interface between gateways, the Smart Metering Protocol could also be used to interconnect other components of the Smart Metering deployment.

Communications between the Home Automation domain and the meter communications unit could also be achieved via a number of different protocols (e.g. ZigBee, AS100 and Bluetooth), that between the meter communications unit and a LAN similarly could be achieved via different protocols (e.g. 802.11 and 802.15.4) and the communications between the LAN and the gateway, or the meter communications units and the gateway also via several different means.

This implies that a well defined layered architecture allowing various protocol implementations to be interconnected in a standardized manner is required.

The set of interfaces identified earlier includes:

- Non-electricity meter - LAN.
- Electricity meter - LAN.
- Home automation sub-domain - LAN.
- LAN - Gateway.
- Gateway - WAN.
- Meter Communications unit - meter communications unit.
- Gateway - gateway.

The LAN and WAN protocols will be taken from existing specifications. The serial interface is also an existing interface and is not considered further in the present document.

The conclusion of this analysis is that the SM European access profile protocol needs to address the gateway-gateway and gateway-WAN interfaces.

Annex D: Traffic Model

The plots shown in clause B.3 for Duty Cycle vs Node population or $P_{success}$ are produced from an Excel traffic model.

A block Diagram of the model is shown in Figure D.1.

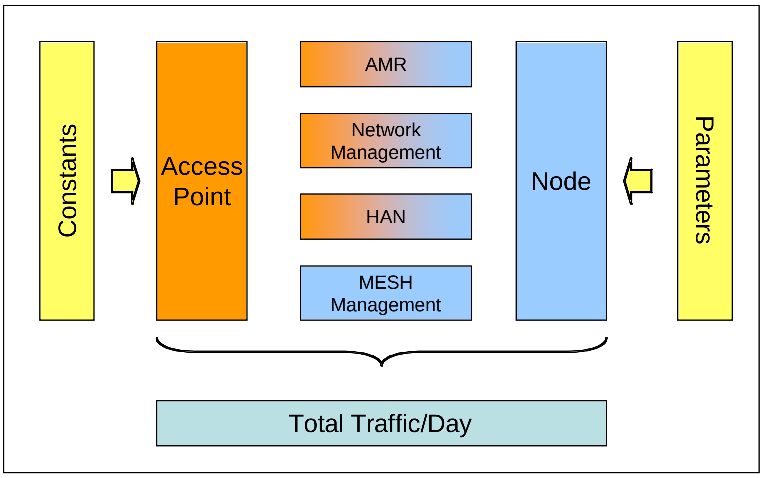

Figure D.1: Traffic Model Block Diagram

The traffic model block diagram identifies the four main blocks of the model. There is a core set of constants for each of the blocks and these are identified and described in Table D.1.

The model is controlled by a number of user definable parameters, as shown in Figure D.2.

Model Control Parameters							
Global Parameters		AMR Parameters		HAN Parameters		L2 MESH Paramaters	
Data Rate	100	Read Uploads per day	6	Number of HAN Devices	2	Number of Neighbours	20
Probability of Success	0.7	Number of channels	2	Packets per Device per Day	2		
MESH Forwarding Ratio	0.7	Samples per day	96				

Figure D.2: Parameter Control Panel

There are 2 categories of parameters corresponding to the Smart Metering applications for automatic meter reading (AMR) and simple consumer devices such as displays (HAN). A third category (L2) allows MESH traffic to be controlled by the number of neighbours within radio range of an average node. The final category, (Global Parameters), sets the Data Rate for the $P_{success}$ computations and Forwarding Ratio, the control parameter for estimating the additional MESH traffic. The ratio represents the additional traffic, owing to forwarding of packets through the MESH, as a percentage of total traffic.

The model automatically re-calculates after any change to the parameter values in the gray areas of the control parameter display.

All computations are performed in functions written in Visual Basic. The model includes a set of constants for the packet sizes for representative Smart Metering applications and expected network management overhead as well as transmission frequencies for each type of traffic.

The functions are called to compute the total traffic per day for each traffic type when the model re-calculates. The total traffic for all types is added and the average traffic per second for a given data rate computed to produce a duty cycle estimate.

The model displays plots of the number of nodes vs duty cycle for traffic computed for APs or nodes for various data rates. These plots allow the required data rate to be identified for a given node per AP population and target duty cycle limit and hence an indication of the channelisation that may be required.

A second pair of plots computes duty cycle vs $P_{success}$ for various populations of nodes. These plots allow considerations of resources which would affect system reliability such as maximum transmit power and the number of available channels or total spectrum.

Table D.1: Traffic Model Constants

Constants for PHY and IP overheads	Description
Const FrameOverhead = 100	Allow 100 octets of PHY frame overhead
Const PacketOverhead = 148	Add in IP and UDP protocol overhead to the PHY overhead
Constants for L2Neighbour traffic	
HelloFrequency As Integer = 12	Node announcement every couple of hours
HelloSize As Integer = 36	Allow 36 bytes for node announcement packet
RefreshFrequency As Integer = 72	Fresh neighbour nodes every 20 mins
RefreshSize As Integer = 18	Half the announcement packet size
NodeInfoFrequency As Long = 288	Broadcast neighbour info every 5 mins
NodeInfoSize As Integer = 36	Use same size as node announcement packet
TimeFrequency As Integer = 48	Update timing every 30 mins
TimeSize As Integer = 12	A long counter
Constants for Network Management	
ConnectionFrequency As Integer = 1	Nodes connect to APs every 2 hours
ConnectionSize As Integer = 60	Allow 60 octets for connection requests
ConnectionResponseSize As Integer = 60	Allow 60 octets for connection responses
DNSFrequency As Integer = 6	Renew DNS lease or other DNS event every 4 hours
DNSSize As Integer = 160	Allow 160 octets of DNS data
DNSResponseSize As Integer = 40	Allow 40 octets for DNS response
NTPFrequency As Integer = 1	Time of Day sync every day
NTPSize As Integer = 10	10 Octets of time request
NTPResponseSize As Integer = 30	30 octets of time update
StatisticsFrequency As Integer = 1	Once a day
StatisticsSize As Integer = 128	Assorted Statistics.
Constants for Advanced Meter Reading traffic	
AMRInfoSize As Long = 1 000	Allow 1 000 octets for accumulated AMR info per day
AMRSize As Integer = 50	Allow 50 octets per packet overhead for AMR protocol
AMRResponseSize As Integer = 30	Allow 30 octets for the AMR acknowledgement
AMRSampleSize As Integer = 8	Allow 8 octets for channel sample
Constants for HAN traffic	
Const HANSize As Integer = 150	Allow 150 octets for the payload
Miscellaneous constants	
SECSPERDAY = 86 400	Seconds per day = 24*60*60

Annex E: Expected Compatibility Issues

E.1 Background

In the summer of 2008 ETSI-ERM sent the ETSI System Reference Document TR 102 649-2 [i.22] to the ECC requesting additional spectrum for SRDs and RFID in two new UHF bands. It proposed that SRDs should operate in the band 870 MHz to 876 MHz at power levels up to 25 mW. e.r.p. In support of this request ETSI TG28 and TG34 undertook a feasibility analysis of interference between short-range devices and RFID systems. This is not repeated here and full details are available in annex D of TR 102 649-1 [i.21].

Independently ETSI GSM-R sent an ETSI System Reference Document to the ECC requesting an extension of their existing band to include the frequencies 918 MHz to 921 MHz paired with 873 MHz to 876 MHz. The frequency band 873 MHz to 876 MHz, is sub-divided into 200 kHz channels to meet the requirements of the GSM structure.

WGFM has looked favourably on this request and it was decided to revise ECC Decisions (04)06 and (02)05 to include E-GSM-R. Germany has already included E-GSM-R in their frequency utilization plan and has also given a license to Deutsche Bahn AG for E-GSM-R. Austria and Switzerland have also allocated the frequency band 873 MHz to 876 MHz to E-GSM-R and it may be expected that other countries will also follow.

The base stations are deployed along the length of the railway track to be covered and these locations are presently limited to urban areas. The mobile subscribers are mounted on board the trains generally in the cab although mobile units operated by maintenance crew from the trackside cannot be excluded

Smart Meters

The proposed frequency band for deployment of the SRD devices in Smart Metering is the EGSM-R band of 873 MHz to 876 MHz. (The upper duplex band of 918 MHz to 921MHz is not considered.) A channelisation scheme of 200 kHz has been assumed in the development of the performance parameters. This also matches the current scheme which was introduced in Japan for Smart Metering and the expected scheme in the US.

E.2 Potential co-existence issues

E.2.1 Introduction

Co-existence may be divided into co-channel and adjacent channel compatibility. The adjacent channel compatibility has already been discussed in annex C of TR 102 649-2 [i.22] and is not considered further here. The remainder of the discussion is focused on co-channel interference.

E.2.2 Geographical location

According to the implementation plans for GSM-R in Europe, E-GSM-R will be used on high speed railway tracks as well as locations with high railway usage, e.g. shunting areas and urban areas. This localisation of E-GSM-R equipment identifies the first potential compatibility issue which will be defined by the geographical location of Smart Meters where these are located adjacent to the railway track. Such collocation will be prevalent in urban areas where scarcity of land for development means both low and high density buildings abut the railway thoroughfare/premises.

One potential solution is to exclude SRD devices from premises within a fixed distance from railway tracks, sidings etc. and this might be accommodated through deployment restrictions. Mitigating factors here include the sectorised antenna used for the E-GSM-R base stations to assure adequate coverage along the length of any track.

A second mitigation factor is inherent in the indoor location of SRD devices which will benefit from the attenuation of the building structure. It is common to use factors of 3 dB for a single course of brick, 10 dB for concrete block and 15 dB for reinforced concrete [i.24] as used in current building practices for apartment buildings which are likely to be located near railway lines.

E.2.3 Duration of transmission

As the E-GSM-R system uses forward error correction of different interleaving depths depending upon whether voice or data traffic is carried, it is generally very robust to interfering signals provided the duration of the interferer is less than half the interleave depth. Under these circumstances the original transmission may be faithfully reconstructed without loss of data. The critical durations for EGSM R are 20 ms for speech and up to 380 ms for data. Consequently transmissions in the same frequency band of duration less than these critical values should not destructively interfere with the intended transmissions of the E-GSM-R system. This has been taken, in the first instance, as a target value for maximum duration of any SRD transmission.

E.2.4 Power of interfering signal

Although SRDs currently have a max power of 25 mW, the critical parameter to evaluate here is threshold of susceptibility of a base station in receive mode at the cell boundary (-94 dBm), as it is here that the equipment will be most sensitive to interference.

E.3 Feasibility of co-existence

Given the possible compatibility issues of proximity and duty cycle, the SRD community was keen to establish the tolerance of GSM-R to interference from a collocated SRD device operating in the same frequency band to determine if coexistence was possible with E-GSM-R (i.e. E-GSM-R MS transmit band) without causing unacceptable levels of interference. As the GSM-R network is used to transfer safety critical information the determination of the effect of collocated SRD devices is crucial if this frequency band is to be used for Smart Metering and Smart Grid applications.

Preliminary co-channel testing in the band 873 MHz to 876 MHz was undertaken by the BNetzA who kindly provided the use of their laboratory at Kolberg in order to conduct some feasibility tests. Details of the test configuration can be found in [i.25].

E.4 Preliminary findings

These tests demonstrated that with an interferer operating at 25 mW with an assumed free space path loss of 60 dB between the source (SRD) and victim (E-GSM-R base station) both data and voice transmissions were possible and within acceptable limits as defined by the E-GSM requirements. (This free space loss was found to be an overestimate of 8 dB and is discussed below.)

Further testing on SRD transmission duration established that the hypothesis outlined above was indeed correct. In voice tests, if SRD transmission times were kept below the threshold values of 20 ms with a recovery period of twice that duration then speech performance was good. An empirical figure of 80 ms was established as the off time for an on time of 20 ms giving a duty cycle figure of 20 %. For data tests a similar relationship was established with a correspondingly longer off time necessary to meet the interleaving criteria.

The outcome of this testing was a parameter set for SRD-LDC shown in combining the voice and data results as follows:

Table E.1: Parameter set for SRD-LDC

Feasible SRD-LDC parameter	Value
Maximum single Tx_{on} period	≤ 25 ms
Minimum Tx_{off} period	≥500 ms
Maximum duty cycle within 1 second	2,5 %

A series of tests were undertaken to estimate the effect of varying power levels on the receive operation. These suggested that the base station was relatively insensitive to a wide variation in power levels with errors only accumulating once a C/I ratio of -60 dB was reached compared to the cell boundary criteria of -48 dB originally established by the test. If the 8 dB overestimate of the free space loss is considered here this would reset the cell boundary C/I at -56 dB. The performance of the system at this level was still adequate. Likewise at a C/I level of 10 dB the errors dropped to zero.

E.5 Discussion

The conclusion of the testing was that without considering any attenuation affects of building materials, a separation distance of 10 m offered adequate protection under the conditions of test. Furthermore the duty cycle established during test suggests that for the deployment conditions envisaged, co-existence with E-GSM-R might be achieved with relaxed duty cycle limits.

What the testing was unable to establish was the effect of multiple interferers which it is expected will operate in an uncoordinated manner. There are two scenarios to be examined. The first is where there are multiple interferers each generating their own traffic within range of a single base station. This can be analysed as a base station located in a population of SRDs. For a population of *(M)* simultaneously active transmitters scattered randomly over an area defined by a radius R from the base station the ratio of power from a single transmitter (*N*) to the aggregated value (*A*) from a population can be shown to be inversely proportional to the duty cycle and the number of active devices [i.26]. This can be expressed as follows:

- Figure E.1 shows that over the range of interest the nearest transmitter will always dominate. When the random nature of traffic generation is considered the interference potential of the population can be reduced to the interference power of the nearest SRD device derived from the preliminary testing.

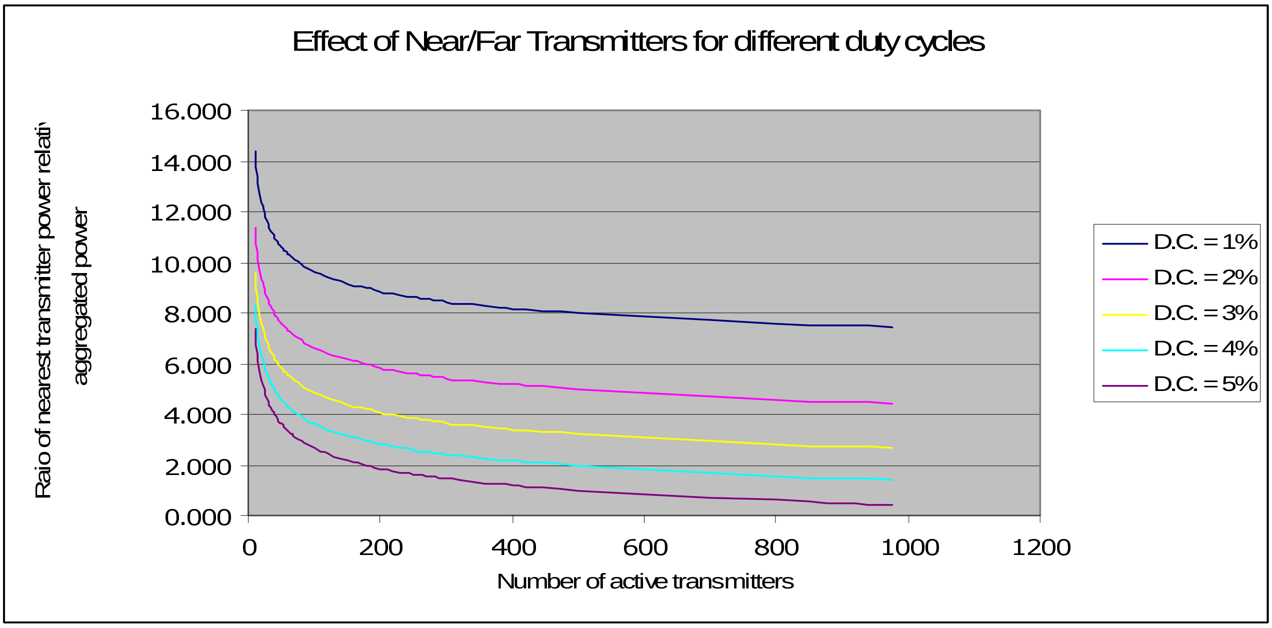

Figure E.1: Near/Far transmitter power with population size

The second case is where there may be one or more nodes acting as the last link in a mesh relay before uplink to the WAN. In the latter case the principal effect is expected to be the perceived duration of the 'on-time' by the base station receiver and further work would be needed here. Of the two effects the latter is considered the more significant.

The insensitivity of the base station to interfering signals of varying power suggests that this parameter will not be the limiting factor for co-existence. Indeed initial work suggests that the power might easily be raised by 6 dB to 10 dB resulting in an operational power output of 100 mW to 250 mW without impacting performance of the E-GSM-R system.

However, there are a number of competing requirements.

Increased power reduces:

- Duty Cycle requirements for a given payload and data rate.
- The number of hops required to send data from source to sink.

The effect of duty cycle can be inferred by reference to Figures B.8 and B.9 of clauses B.3.6 and B.3.7. The second point might be inferred from Figures B.10 and B.11 from clause B.3.8. These effects act in concert to maximize the use of available spectrum. A consequence of these two factors for a fixed packet size and data rate is to reduce the level of mutual interference since the likelihood of colliding packets will fall in this Aloha based system.

Increased power would also enhance/improve the transmission performance of devices which either are buried or located in basements. However, whilst increased power will improve the transmission performance of so located devices, those not located in buildings may give rise to some localised "hot spots". Although the proportion of devices not located in buildings would only be known after a deployment plan had been made, this is expected to be less than 5 % of the total number of devices. Under these conditions Transmit Power Control (TPC) might be used to assure an adequate margin necessary for a stable communication link without compromising the E-GSM-R system through the use of excess power.

Whilst increased power is highly desirable, battery devices have power limitations. In these cases, system trade-offs need to be made between:

- low overall average power consumption;
- low system power consumption but increased transmit power.

The first power consumption strategy will limit:

- transmission range;
- data rates.

And will require a high density of nodes which will increase the likelihood of on-air collisions.

The second strategy will support greater:

- transmission range;
- data rates.

And require fewer nodes, reducing the risk of on-air collisions.

These tradeoffs can be minimised by suitable design of MAC/PHY layer protocols which can be complemented by TPC. The choice of power consumption strategy will be device and installation dependent and this is left to the system integrator.

From the work undertaken so far and in the particular deployment scenario foreseen, a number of lines of investigation arise:

- the adequacy of a 10 m exclusion perimeter from the railway trackside for SRD devices used in Smart Metering;
- the possibility of raising the power for Smart Meter devices to include a figure for building attenuation;
- increasing the duty cycle to 2,5 %.

Annex F: Detailed Market Information

F.1 Metering installed base.

The following information is drawn from industry sources compiled by the European Smart Meter Interest Group (ESMIG) [i.12] for gas and electricity meters and the European Smart Metering Alliance (ESMA) [i.14]. The market information offers combined figures for residential, industrial and commercial meters.

F.1.1 Size of the existing installed base by country within Europe

The installed base of electricity meters by country is shown in Figure F.1.

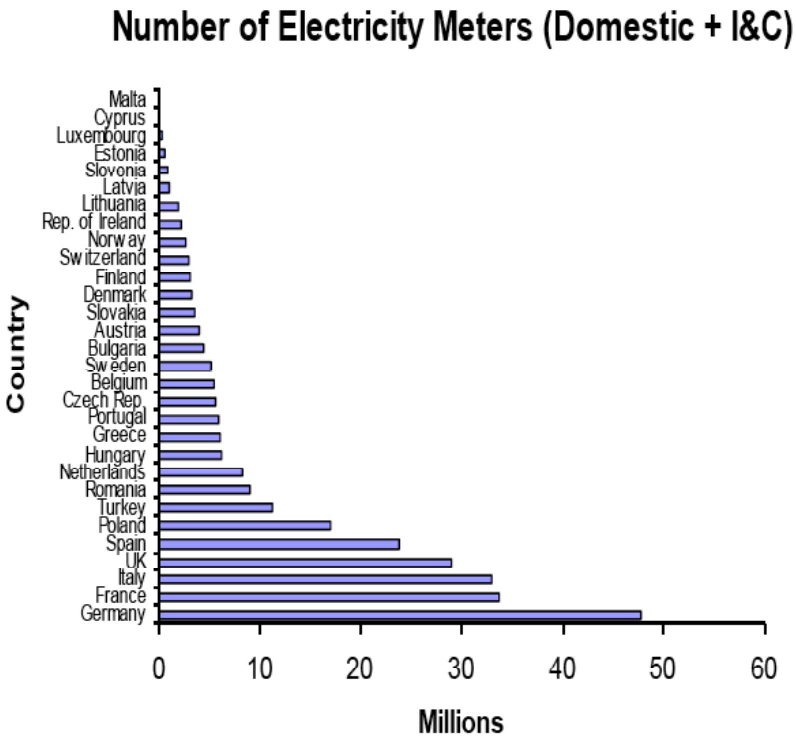

Figure F.1: Installed base of electricity meters in Europe (from [i.12])

The installed base for gas meters by country is shown in Figure F.2.

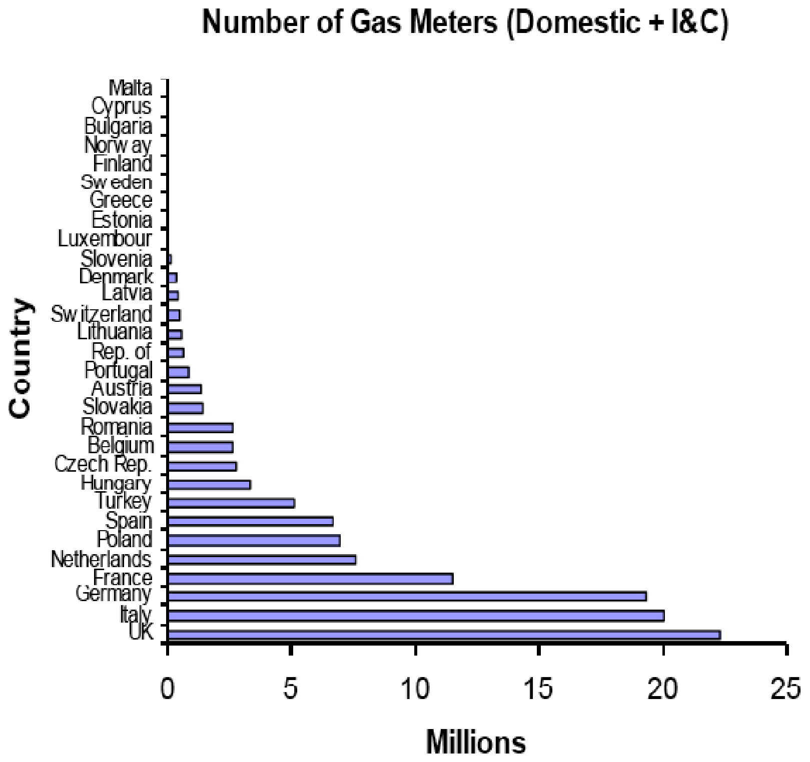

Figure F.2: Installed base of gas meters in Europe (from [i.12])

F.1.2 The roll-out of Smart Meters into the existing markets

The development of each market is closely linked to the member country's domestic political and competition agenda; these are addressed in [i.14]. The detail in Table F.1 is drawn from ESMA's annual report on Progress in Smart Metering [i.14].

Table F.1: Smart Metering roll-out in Europe

<table>
<tr><th>Country</th><th>Electricity</th><th>Gas</th><th>Water</th></tr>
<tr><td>France</td><td>Target of 95 % of all meter by 2020</td><td>Roll-out under discussion</td><td>Information not yet available</td></tr>
<tr><td>Germany</td><td colspan="2">Smart Meter requirements expected by 2011. Presently only small trials on electric meter readings</td><td>Information not yet available</td></tr>
<tr><td>Italy</td><td>Currently 33 million devices installed with a further 3 million to be completed by 12/2011</td><td>Target of 80 % of all meters by 2016; approx 16 million</td><td>Information not yet available</td></tr>
<tr><td>Netherlands</td><td colspan="3">Have multi-utility functionality specification which uses the electricity meter as the communication hub. Compulsory roll-out to all customers has been challenged and a parliamentary decision is awaited. A revised schedule will be issued then</td></tr>
<tr><td>Poland</td><td colspan="2">Smart Metering deployed in the industrial sector on a voluntary basis. A compulsory roll out is expected to begin in 2010 with a completion date of 2017</td><td>Information not yet available</td></tr>
<tr><td>Spain</td><td>A staged roll-out is planned for domestic meters:
30 % before 12/2010
20 % before 12/2012
20 % before 12/2015
30 % before 12/2018</td><td>Information not yet available</td><td>Information not yet available</td></tr>
<tr><td>UK</td><td colspan="2">Planned roll-out of 52 million meters between 2012 and 2020</td><td>Information not yet available</td></tr>
</table>

Water Meters

The European installed base of water meters is approximately 157 million. The growth of smart meters worldwide is expected to rise to 31 million by 2016. According to Pike research 31,8 % of all new meters will be smart meter.

Annex G: Charge Station Standardisation and Infrastructure

G.1 Charge Station Standardisation

Critical to the uptake of electric vehicles will be standardised charging systems. The standardisation activities for charging stations has begun and key initiatives are cited in Table G.1. However, as can be seen from Figures G.1 and G.2, many of the ideas are concepts and there remains considerable work to do.

Table G.1: Standardisation activities for Electric Vehicles and their infrastructure

Standard	Title
IEC 61851-1 [i.43]	Electric vehicle conductive charging system - Part 1: General requirements
ISO TC22 SC21	Electrically propelled road vehicles
IEC/TC69WG4	Power supplies and chargers
IEC SC23H	New proposal for standard coupler
IEC 62196-1 [i.44]	Plugs, socket-outlets, vehicle couplers and vehicle inlets - Conductive charging of electric vehicles -
IEC 60309 [i.42]	European approved wiring devices (-1 general requirements, -2 dimensional requirements)
IEC 60309 [i.42]	Plugs, socket-outlets and couplers for industrial purposes/charging concept
CLC/TC69X/WG3	Pluggable connectors for charge stations

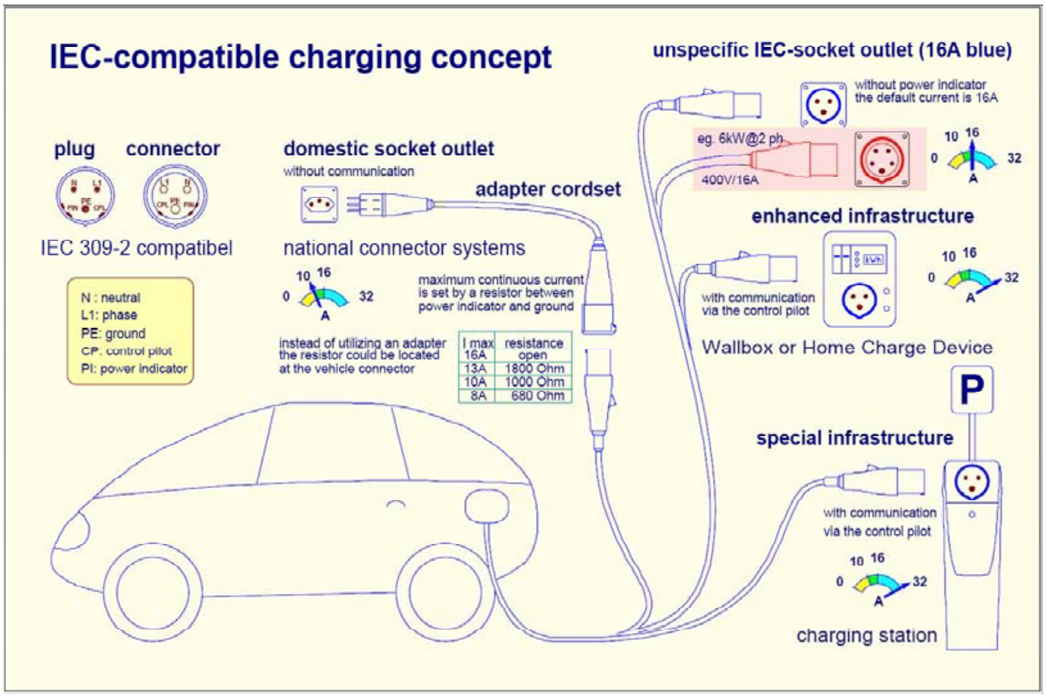

Figure G.1: IEC Charging Concept

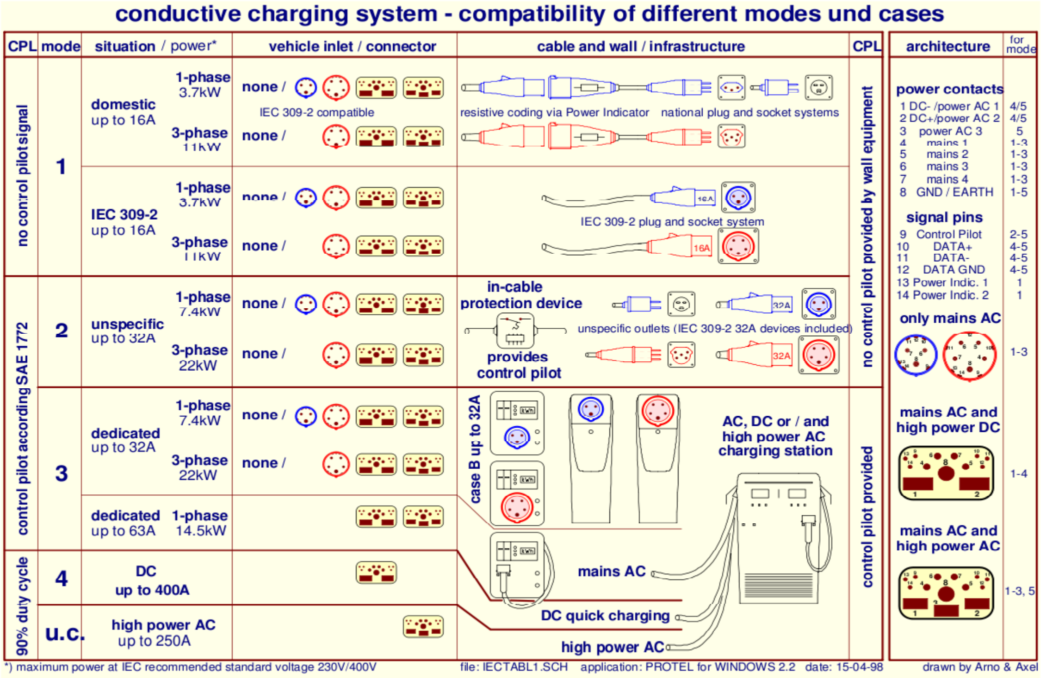

Figure G.2: Compatibility of different charging systems

In spite of these challenges a number of companies are designing and building charging stations for the charging infrastructure.

G.2 Infrastructure

The development of infrastructure is geographically limited and presently concentrated in urban areas. To extend vehicle range and increase the rate of adoption, a number of manufacturers enable their cars to be charged at conventional main power supplies, which is available nearly everywhere. This is not without its own difficulties since without high capacity outlets charging times will increase making extra-urban travel less appealing. The Swiss Ministry of Energy is the first European body to address the need for a common infrastructure.

To permit the necessary customer identification and associated service level agreements and tarrifing, charging stations will require a communications channel to the energy supplier. This communication channel to the energy supplier will also offer a number of new features of interest for energy suppliers, e.g. controlling of charging cycles to smooth peak loads in the energy consumption. In the future, when large numbers of electrical cars will be used, it will be possible to buffer the unbalanced energy quantity generated from regenerative sources. Furthermore, for the customer, new pricing strategies for electrical cars will be possible.

G.2.1 EV Charging Infrastructure

The Swiss Ministry of Energy commissioned a study to define an EV charging infrastructure which was published in 2008 (see [i.47]). The purpose of this project was to develop and to demonstrate the feasibility of a cost effective and comprehensive EV-infrastructure system in three steps:

- Definition of the architecture
- Implementation of the system in a test market place
- Commercialisation of the system

Technical considerations arise from a consideration of the location of the interfaces illustrated in Figure G.3.

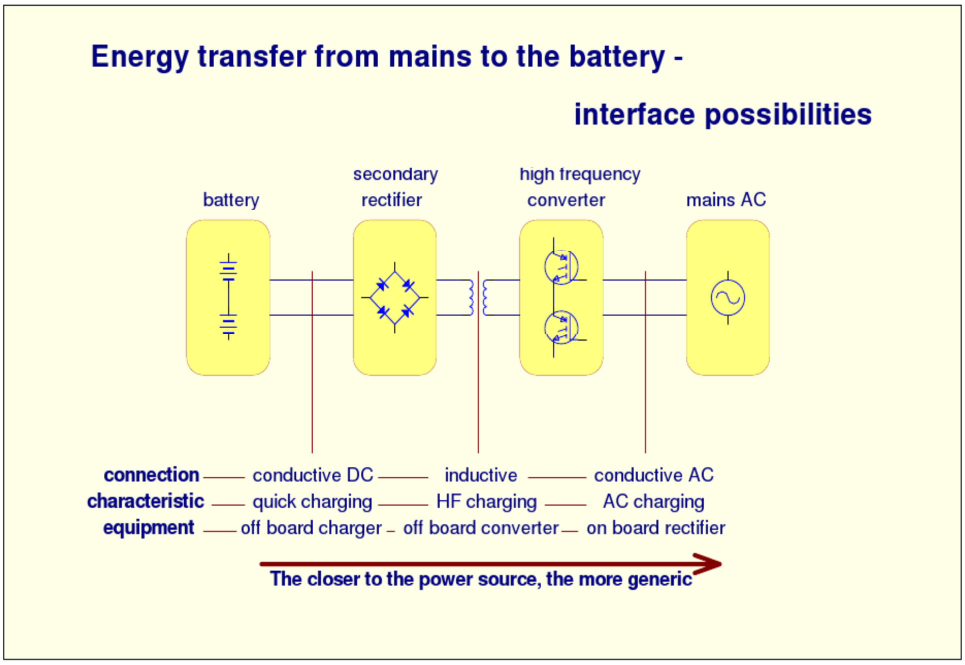

Figure G 3: Location of charging interfaces

1) The closer the interface is located to the battery, the more varieties of vehicle layout have to be covered by the fixed equipment. Consequently, an interface at the DC side has to cover all present and reasonable future EV-demands. It should also allow home charging at common AC sources and be based on an international agreement about the physical and functional design.

2) Supplying AC to the vehicle requires all conversion stages on board. However, the charging system is entirely part of the vehicle's design. Consequently, an exclusively AC interface at the vehicle prevents it from quick charging. An interface at the fixed part of the supply could be tailored to the demand, without restricting vehicle designs.

From this brief examination four charging modes are possible; the benefits and challenges are given in Table G.2.

Table G.2: Infrastructure charging mode options

Charging mode	Benefits and Challenges
DC charging (quick charging)	DC charging allows almost unlimited power, therefore it is so far the favourite concept for quick charging implementation. The specifications of the off board power source are quite challenging, especially if it is not dedicated to a certain EV-type.
Inductive charging (via an inductive coupler)	It is possible to adopt different battery voltages in some discrete steps. The limitation comes from the operating point. At low power rates efficiency decreases, which makes the system inadequate to top up batteries.
Mains AC conductive charging	Direct connection to mains provides the most freedom to the vehicle design but is restricted to a certain power level. The on-board charging equipment is very cost sensitive. On the other hand, there is a very low initial effort to develop infrastructure. However, amendments are necessary to provide a practical and competitive charging facility.
High power AC charging	High Power AC sources could also be used to charge a traction battery via the traction inverter. In this case the voltage adaptation is realised by an off-board mains transformer.

G.2.2 Charging Station Plug Communication Components

Current standards addressing communications require an additional contact in the plug and socket system, whereas the current developments prefer communication through powerline. The key characteristics of vehicle/charging communication are identified below.

Communication between vehicle and charging station:

- identification of vehicle-code (e.g. for assignment of the vehicle to the account of the owner at the power supplier);
- identification of the charging system of the vehicle (what kind of charging is needed?);
- identification of accurate connection between vehicle and charging station;
- accomplishment of RCD Control;
- clearance and termination of charging process;
- signal for interlocking of charging system;
- activation of immobilizer system.

Communication between vehicle and power supplier:

- billing of delivered power;
- controlled supply of power;
- provision of different rates
- for the future: controlled use of vehicle battery as power reservoir;

A similar set of requirements is captured in TS 102 890 [i.45].

A prototype device is shown in Figure G.4.

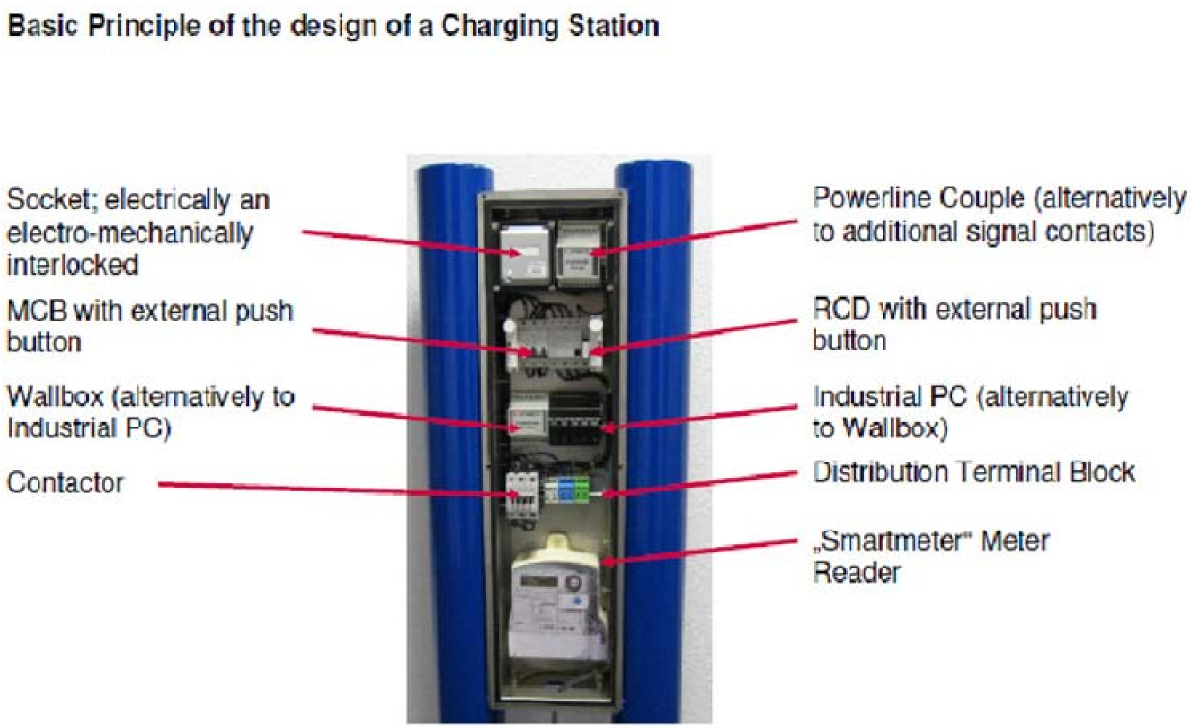

Figure G.4: Prototype charging station

History

Document history		
V1.1.1	July 2011	Publication