D6.1.1: Consolidated communication requirement descriptions

Revision History

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Abstract

This report contains the detailed power and communications system scenario data which will be used in subsequent LTE network dimensioning studies.

The scenario is based on selected use cases of the Vattenfall / Finland distribution system network which require wireless communications.

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1 Preface

This report was done as a part of the Finnish national research project "Smart Grid and Energy Market" SGEM.

It was funded by Tekes – the Finnish Funding Agency for Technology and Innovation and the project partners.

I would also like to thank our partners Vattenfall, TeliaSonera, Violasystems and Emtele for providing background information and the good cooperation.

2 Scope

This report contains the detailed power and communications system scenario data which will be used in subsequent LTE network dimensioning studies.

The scenario is based on selected use cases of the Vattenfall / Finland distribution system network which require wireless communications.

3 Introduction, Motivation and Methodology

For the 2nd FP of SGEM more detailed LTE radio and core network dimensioning studies will be carried out and documented by Nokia Siemens Networks in deliverable D6.1.3 "Advanced Smart Grid communication concept". These dimensioning studies will gauge the amount and impact of SG communications traffic and will allow comparisons to the mobile broadband traffic carried in LTE networks. These LTE network dimensioning studies will also be the basis for possible further economic studies in SGEM FP3 such as CAPEX / OPEX comparisons for various LTE deployment scenarios and configurations.

For utility communications it is necessary to consider in addition to the average SG data traffic volumes also the peak loads during larger scale power outages and faults (e.g. due to many simultaneous alarms of meters / RTUs). Any limitations in the communication system due to congestion would impact the useful functionality which could be implemented into DMS.

SG related communications requirements are very use case specific. In particular, the modeling of use cases related to power outage and fault scenarios which may result in high or peak session densities (signaling transactions) require detailed input assumptions in order to obtain realistic results. These cannot be easily found in the open literature. While the use case volumetric data collected by NIST [4,5] covers a broad range of future SG use cases, the detail of this data is considered as not sufficient to study the relevant distribution automation use cases in Finland in depth.

In order to make the LTE network dimensioning studies concrete, a case study approach is therefore proposed. As the Vattenfall / Finland distribution system possess already today a high degree of automation and also makes extensive use of wireless communications (based on GPRS), it is an ideal starting point for defining meaningful power and communications system scenario data.

In a first version of this report this will be done for today's use cases such as AMR, use of AMR alarms in DMS for MV/LV outage management and MV feeder automation. This will establish a baseline scenario which can be verified against empirical data obtained from current communication arrangements. In a revised version of this report more speculative SG use cases will be added which could materialize around 2020 such as more advanced distribution automation concepts, secondary substation automation, DR, etc.

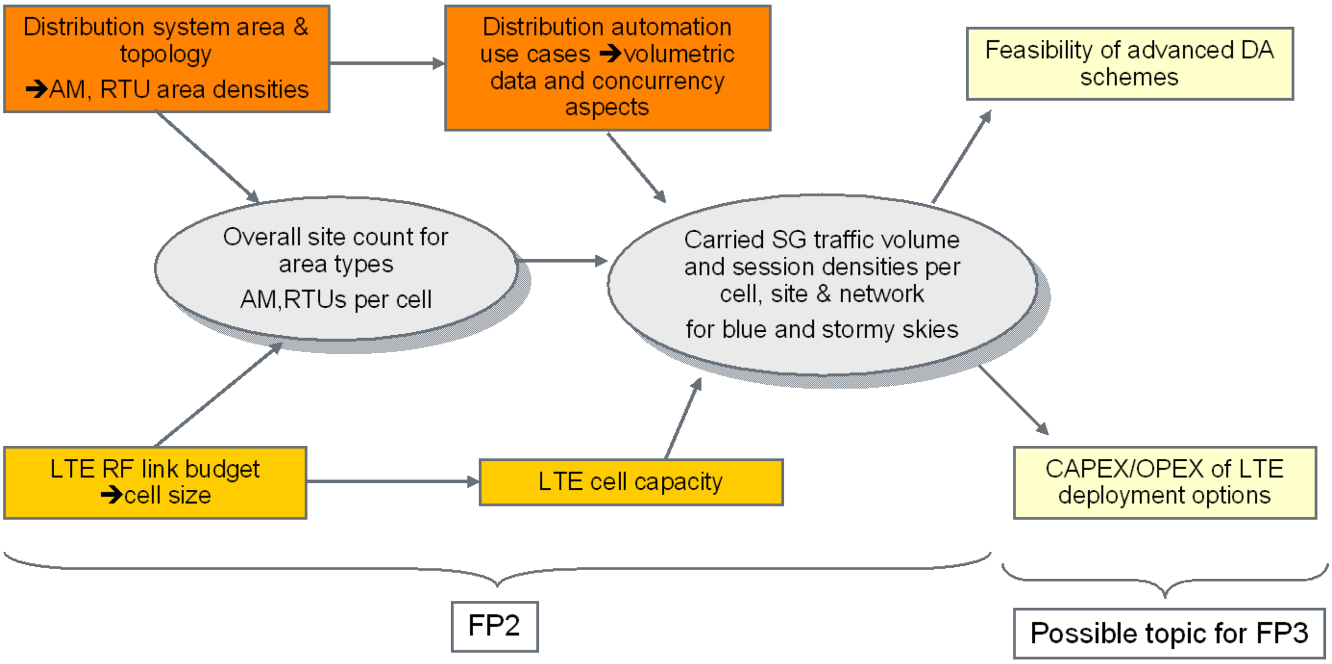
The related communications traffic with the field devices (automatic meters, RTUs) is assumed to be carried exclusively wirelessly and furthermore, is assumed to be aggregated into a single LTE network.

Two LTE deployment scenarios are considered:

- a typical CSP provided LTE MBB network as well as
- a dedicated LTE network for the utility in which coverage is optimized.

Fig. 3-1. shows the proposed methodology for the LTE network dimensioning case study. Previous work for GPRS along similar lines can be found in [13].

Fig. 3-1. Proposed methodology of the LTE network dimensioning case study



In this deliverable detailed parameters related to the colored boxes are collected:

Distribution system area & topology:

- % distribution of area types (urban, rural,…)
- average amount of MV, LV feeders, transformers and customers per area type
- average length of feeders
- AM, RTU densities per area type

Distribution automation use cases volumetric data and concurrency aspects:

- selection of relevant use cases and their underlying communication events
- communication transactions and data volumes related to the events

- protocol overheads (TCP/IP, VPN, heartbeat,...)
- event frequencies (e.g. fault+alarm frequencies, meter reads)
- concurrency aspects of events (e.g. how many meters are read per hour, how many alarms occur per hour during storms)
- how meter traffic (reads, alarms) are concentrated / configured behind concentrating modems

It is expected that some additions and corrections of the event related parameters are needed in order to calibrate the scenario against actual communication volumes. These will be provided in a corrected version of this report as part of the analysis work around D6.1.3.

LTE Radio link budget (RLB), cell size:

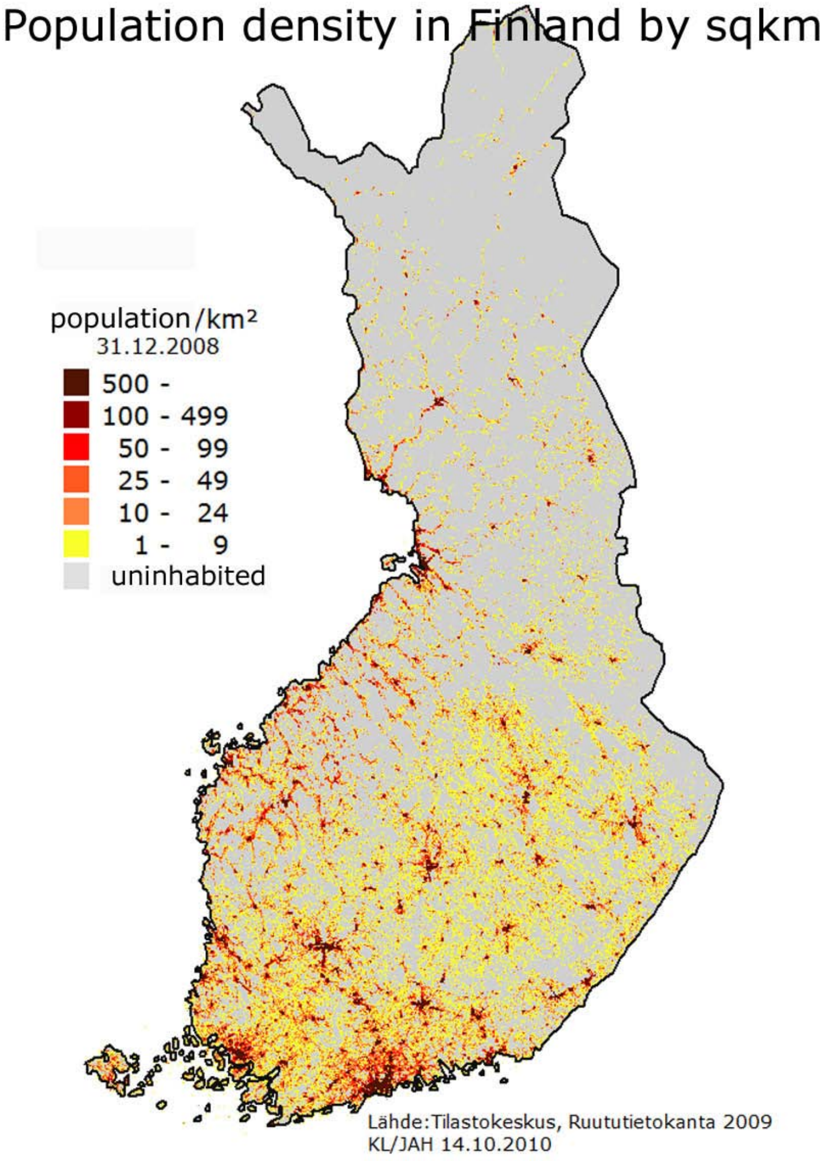
- AM, RTU related RF site parameters needed for RLB

These data is captured in suitable EXCEL files to facilitate further analysis in subsequent deliverables.

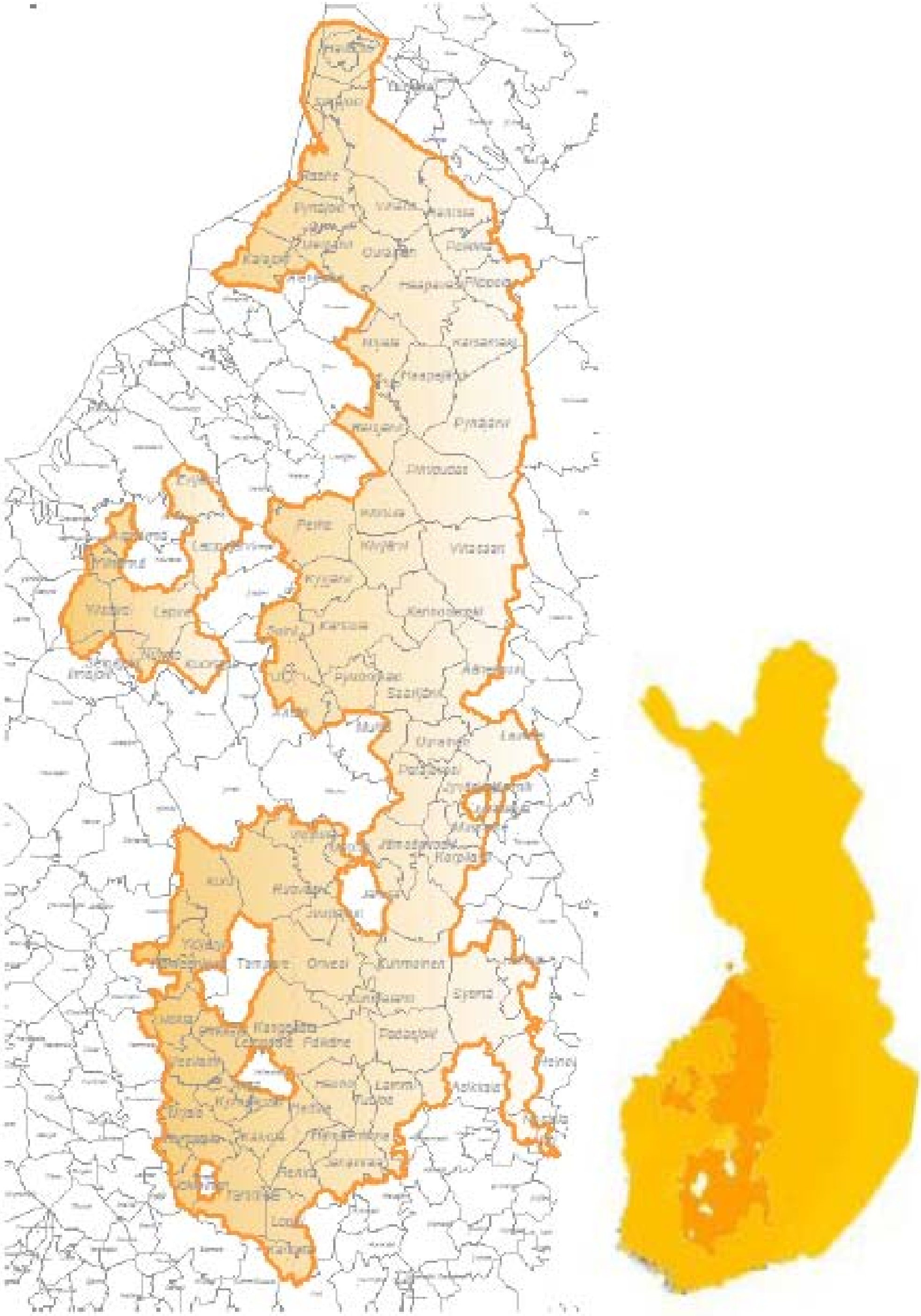
4 Scenario for communication requirements

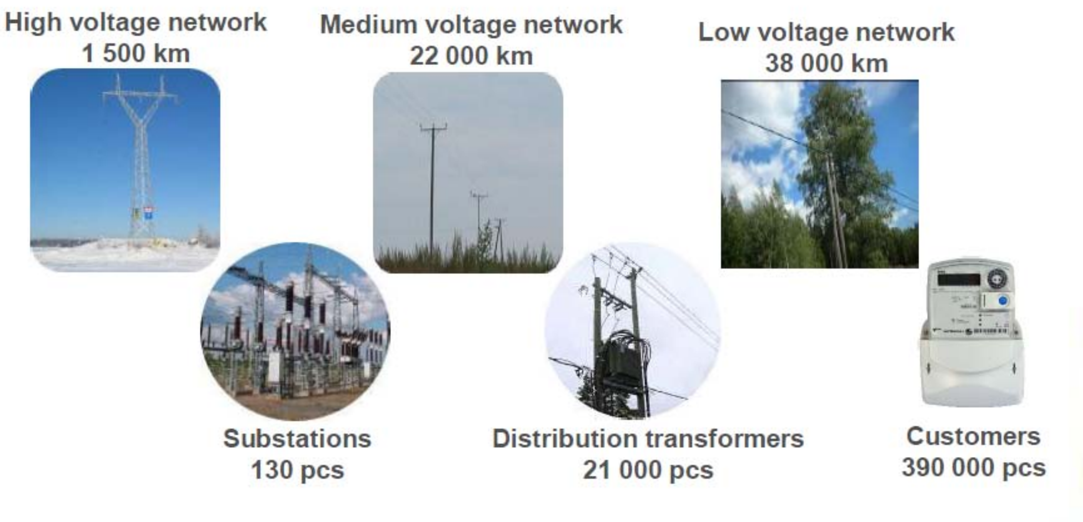
4.1 Utility Service area and Distribution system topology

The following figures provide an overview of the chosen Vattenfall / Finland distribution system scenario:



Vattenfall / Finland distribution system service area:





The Vattenfall / Finland Service area and Distribution system topology is approximated by the following more specific scenario data in Table 4.1-1. This data will be subsequently used for LTE network traffic dimensioning according to the methodology as per Fig. 3-1.

The provided numbers are not exact, but should be in the right ballpark in order to derive representative area densities for meters and RTUs. Compared to the rural area, the margin of error in these assumptions is certainly larger for urban and suburban areas due to their small size and high power density.

Table 4.1-1

			Utility service area			
	Urban	**Suburban**	**Rural**	**Total**		**Remarks**
Area, %	0.19	2.34	97.47	100.00	%	
Area, km^2	**94.1**	**1147.2**	**47758.7**	**49000**	**km^2**	**49000**
			Power System Topology			
	Urban	**Suburban**	**Rural**	**Total**		**Remarks**
HV/MV substations	13	20	104	137		137
HV/MV substation area	7.2	57.4	459.2		km^2	
MV feeders / substation	8	6.5	6			
MV feeders	104	130	624	858		
Length per MV feeder	4	9	33		km	
Length of MV feeders	416	1170	20592	22178		22050
MV/LV transformers / MV feeder	6.1	13.5	30.5			
MV/LV transformers	634.4	1755	19032	21421.4		21523
MV/LV transformer density	6.7	1.5	0.4		trafos/km^2	
LV feeders / MV/LV transformer	4	3.5	3			
LV feeders	2537.6	6142.5	57096	65776.1		
Length per LV feeder	0.24	0.39	0.615		km	
Length of LV feeders	609.0	2395.6	35114.0	38118.6	km	38253
customer sites / LV feeder	20.5	13.7	4.5			
customer sites / MV/LV transformer	82	48	14			
customer sites / MV feeder	500	647	412			
customer sites / HV/MV substation	4002	4208	2471			
customer sites within area	52021	84152	256932	393105		394722
customer site density	552.65	73.35	5.38		cust/km^2	8.06
customer peak power (average)	6.5	5.5	3.0	4.00	kW	peak hour load / customer (rough estimate, averaged over all services)
power density (calculated)	3.592	0.403	0.016		MW/km^2	
power density (actual)	3.592	0.403	0.016		MW/km^2	
req MV/LV transformer rating	1066.0	527.5	81.0		kVA	50% loaded
req HV/MV transformer rating	37.2	33.1	10.6	16.41	MVA	70% loaded, average 17 MVA
fraction 3-phase / 1-phase customer sites	0.9	0.9	0.9			most alarms can only come from 3-phase AM

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AMR						
AM	52021	84152	256932	393105		100% AM penetration
AM density	552.65	73.35	5.38		AM / km^2	
% of AM behind concentrator modem	30	20	0		%	
AM / concentrating modem	15	15	1			Iskra P2CC RS-485 'concentrating' modem handles meter COSEM traffic transparently => no data storing or protocol conversions
concentrating modems	1040	1122	0	2162		
directly connected AM	36415	67322	256932	360668		
MV Feeder automation						
	Urban	**Suburban**	**Rural**	**Total**		**Remarks**
Gateway for HV/MV substations backup comm's	3	9	104	116		
Gateway density	0.0319	0.0078	0.0022		gateway/km^2	
Recloser RTUs	0	30	100	130		
Recloser RTU density	0.0000	0.0262	0.0021		RTU/km^2	
Disconnector RTUs	20	300	1350	1670		
Disconnector RTU density	0.21	0.26	0.03		RTU/km^2	
Connected field devices						
				Total		**Remarks**
# of connected radio modems in the field				364747		Subscriptions

4.2 Fault frequencies

Faults are linked to communication events such as alarms or meter queries. These event frequencies will be later related to MV fault frequencies which are considered therefore first.

4.2.1 MV Fault statistics from 2010

The following figures copied from [11] provide MV faults / 100 km as an average across most Finnish distribution system companies (not just VFV).

Fig. 4.2.1-1. MV faults / 100 km / a (from [11])

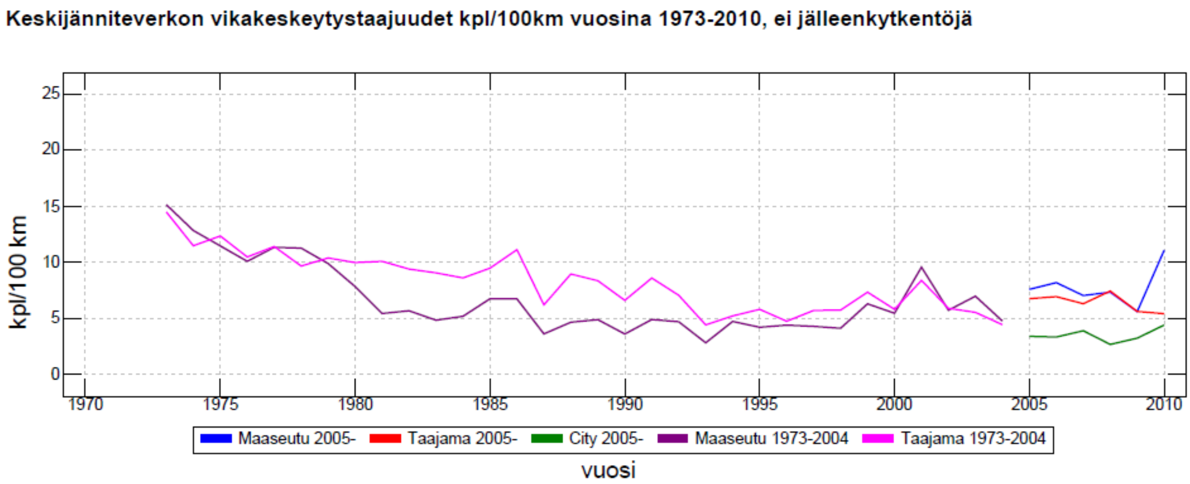
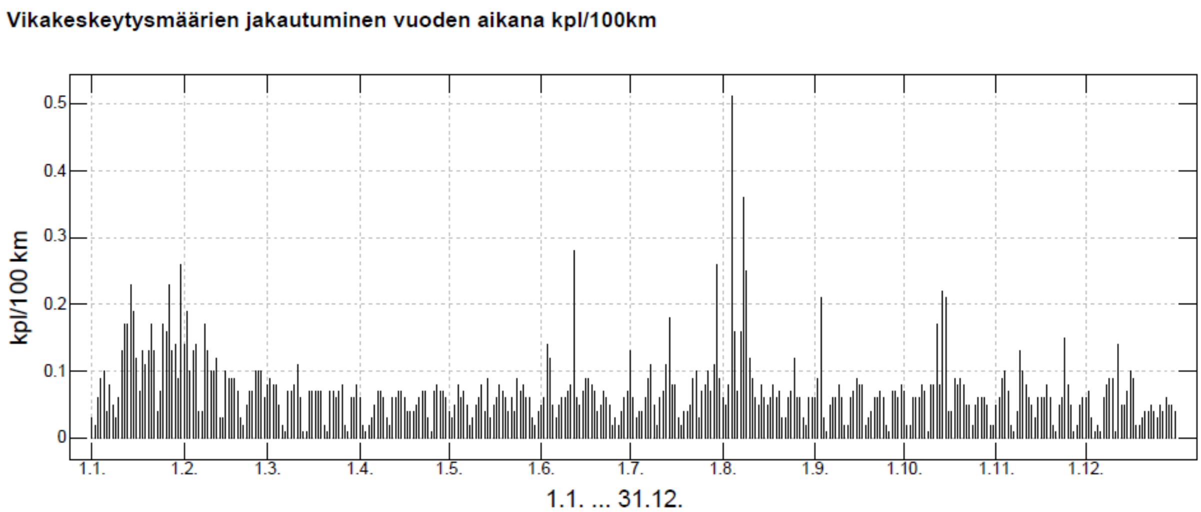
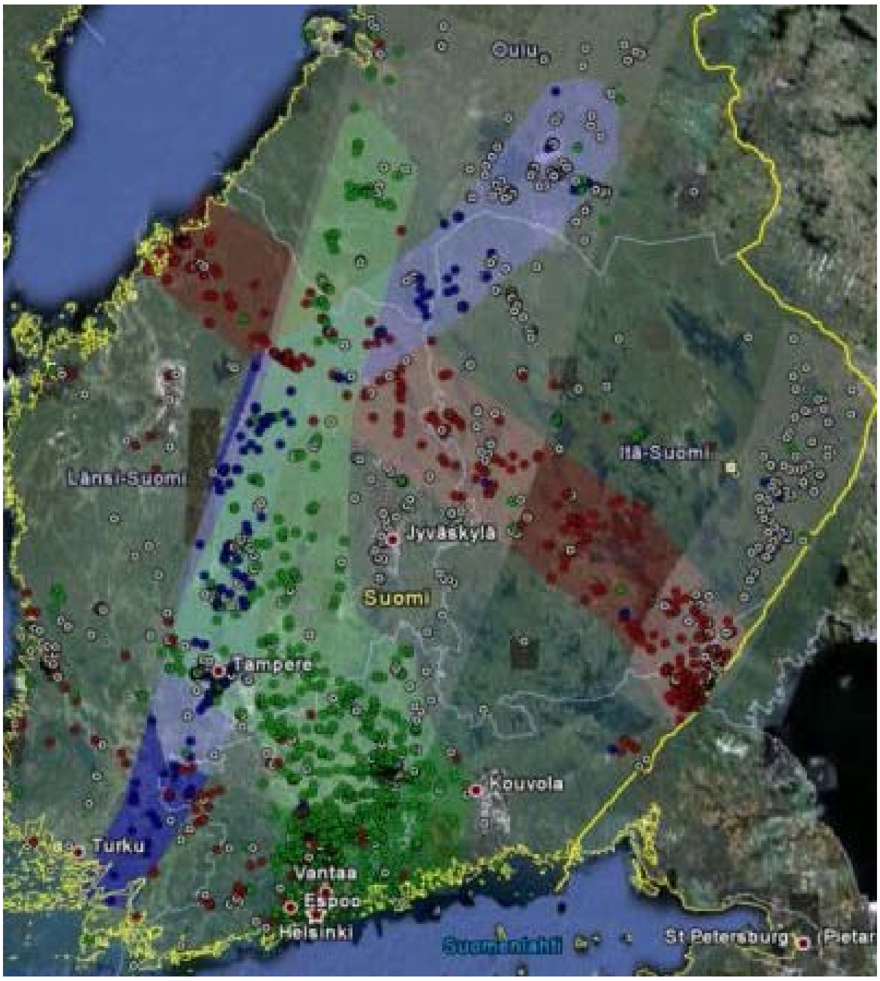
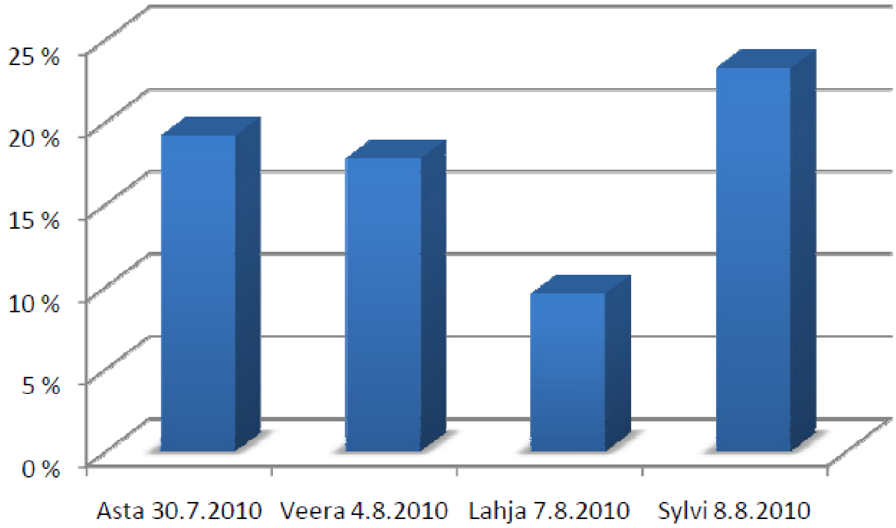


Fig. 4.2.1-2. MV faults / 100 km / d (from [11])



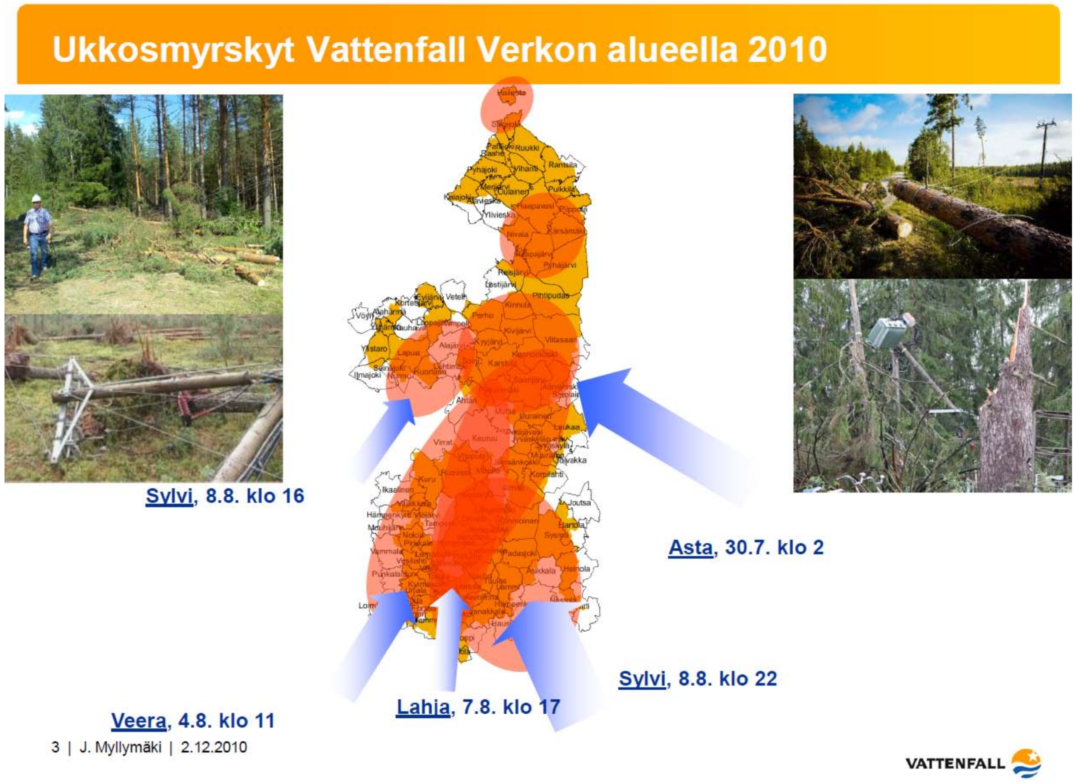
The peaks around beginning of August (4-9.8) were due to severe storms. A summary of the storm impact can be found in [10] from which also the next 2 figures are taken:

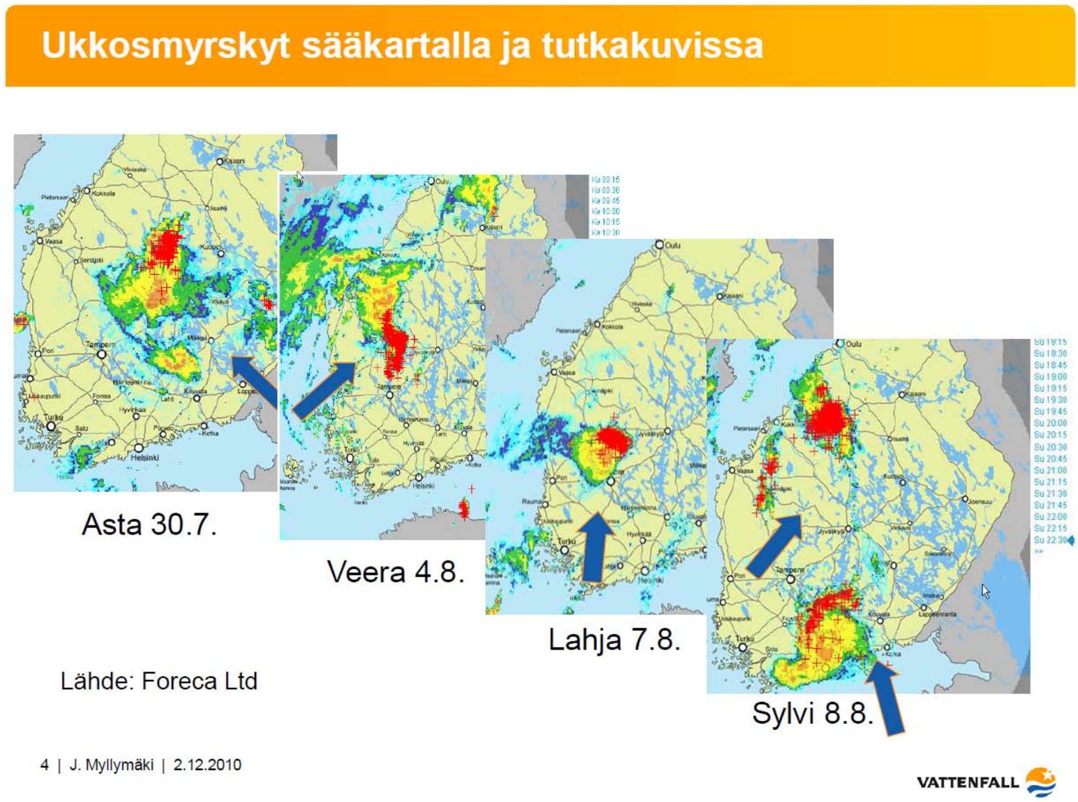


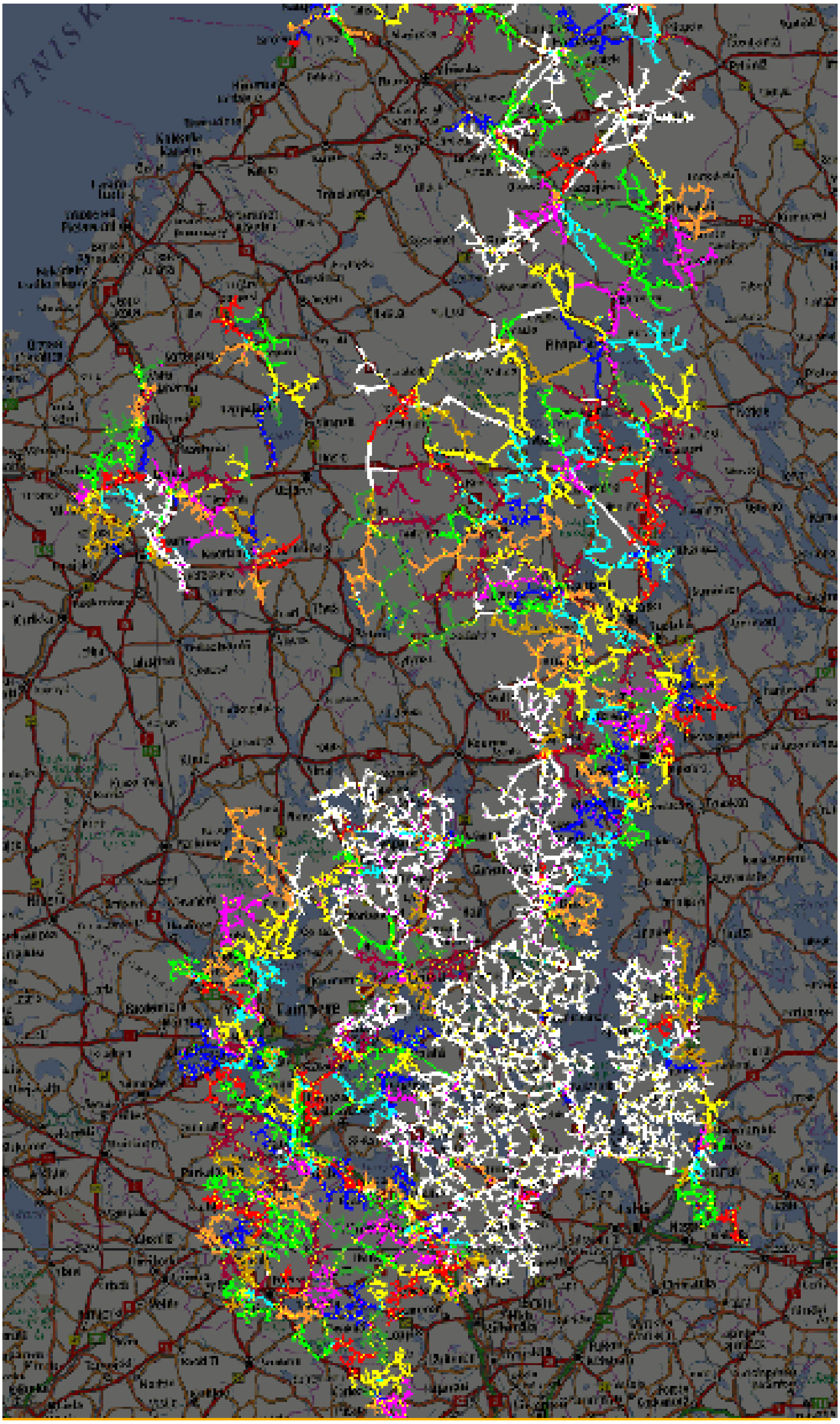


Kuva 2. Kesän 2010 myrskyjen jakautuminen kyselyyn vastanneilla verkonhaltijoilla.

The following slides borrowed from [9] describe in more detail the impact on the VFV distribution network:

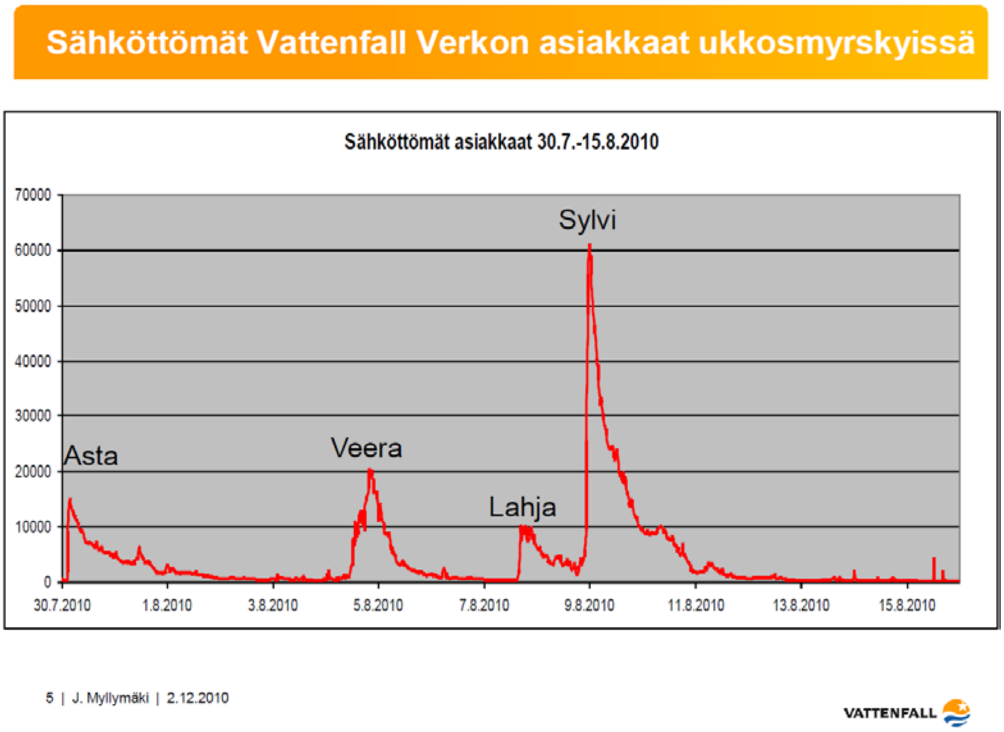






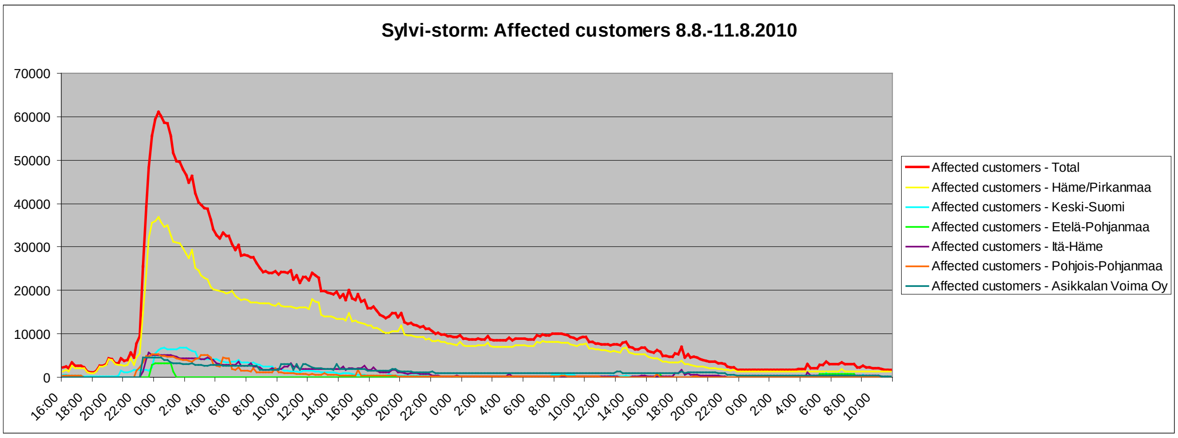
The following slides, also borrowed from [9], will show increasingly more detail about the worst storm for VFV – Sylvi.

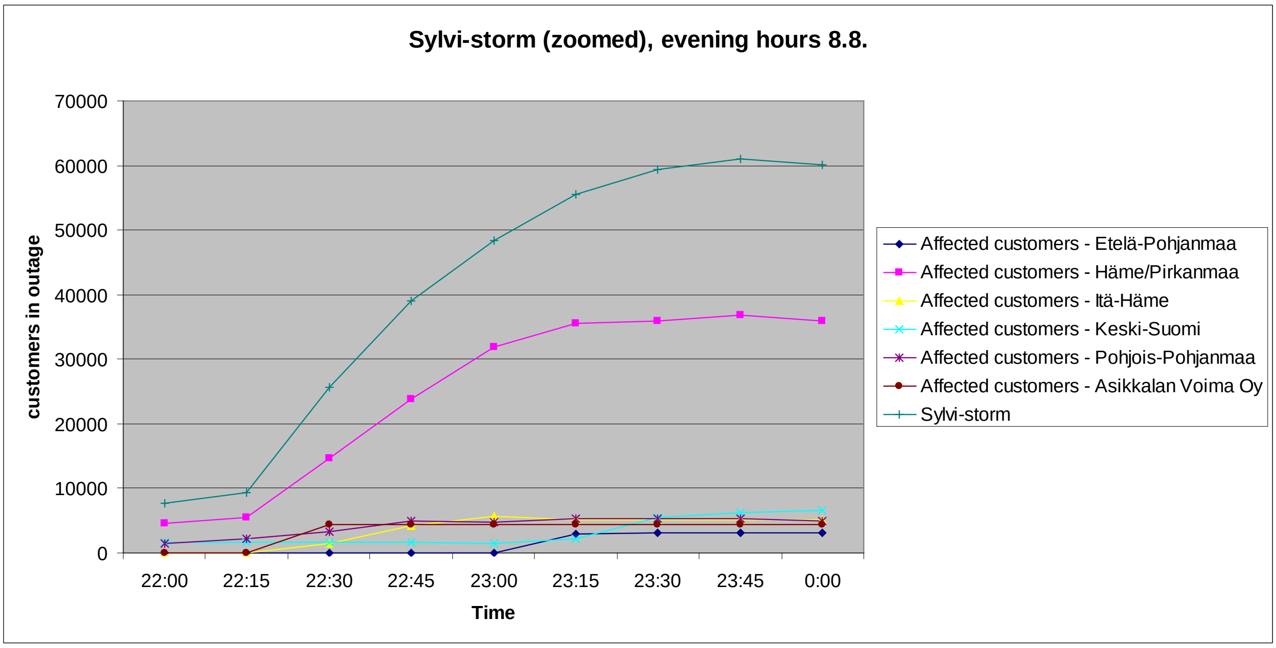
Fig. 4.2.1-3. Customer outages (from [9])



The progression of customer outages during Sylvi is shown more clearly in Fig. 4.2.1-4:

Fig. 4.2.1-4. Sylvi induced customer outages





4.2.2 MV Fault frequencies

From the data in section 4.2.1 we will derive MV fault frequencies as follows:

Yearly average MV fault frequency: for rural area Fig. 4.2.1-1 shows around ~11.1 MV faults / 100 km / a, however, this is an average across nearly all distribution system operators in Finland of which 65% were not affected by the storms [10]. Assuming for the unaffected distribution system operators 7.5 MV faults / 100 km / a, i.e. a value close to the average over the last years, we obtain for the other 45% of distribution system operators affected by the storms an adjusted value around 15.5 MV faults / 100 km / a, i.e. ~1.4x the values from Fig. 4.2.1-1. This results for the VFV area in

Yearly average fault frequency (2010)					
	Urban	Suburban	Rural	Total	
MV faults / 100 km / a	6.3	7	15.5		f / 100 km / a
MV faults / a	26.2	81.9	3191.8	3299.9	f / a
MV faults / h	0.003	0.009	0.364	0.377	f / h

However, storms tend to make the fault event rate rather ‘peaky’, i.e. non-uniformly distributed in both time and (geographical) area domain. We will consider hourly peak MV fault frequencies.

Hourly peak MV fault frequency, within whole system area, during Sylvi storm:

A. From Fig. 4.2.1-4. we find at 22:15 the highest rate of power outages of 15000 outages / 15 min, i.e. 45000/h across the VFV system. Table 4.1-1 shows 412 customers per rural feeder which have on average ~2 disconnectors which results in a lower number of customers in outage per MV fault; let us assume here 275 instead of 412. This gives a rate of 45000/275 = ~164 MV faults/h.
B. VFV quoted 600 MV faults due to storms of which ~57% or 342 faults are due to Sylvi by inspection of Fig. 4.2.1-3. From Fig. 4.2.1-2 we see that around 50% or 171 of the Sylvi induced faults occurred in the evening of 8.8., the remaining ones during the following 2 days. Fig. 4.2.1-4. shows that 90% of these 171 faults occurred between 22:15 and 23:15, i.e. within 1 h or at a rate of ~154 MV faults/h.
C. Fig. 4.2.1-4 shows for the 8.8 ~0.36 MV faults/100 km/d averaged across all distribution system operators in Finland. However, according to [10] only 21% of the distribution system operators were affected by Sylvi, so this value should be adjusted upwards by a factor of 2.3 resulting in ~0.83 MV faults/100 km/d or for the rural VFV area 170.6 faults. Assuming 90% of these within 1 h gives a rate of ~153.5 MV faults/h.

These results are well aligned and summarized as:

Hourly peak fault frequency, within whole system area, during Sylvi storm					
	Urban	Suburban	Rural	Total	
Peak-to-Average Event Rate (time) PAER_time	431	431	431		
peak MV faults / h	1.29	4.03	157	162.32	f / h

During the worst hour of Sylvi the Peak-to-Average Event (=fault) Rate increased in the time domain by a factor of ~431 compared to the yearly average.

However, storms tend to make the fault event rate also non-uniformly distributed in the (geographical) area domain which needs to be considered when computing cell peak loads.

Hourly peak MV fault frequency, within affected area, during Sylvi storm:

Fig. 4.2.1-4 shows that during the worst hour of Sylvi around 35500 or 65% of the faults occurred in Häme/Pirkamaa region alone. From the above figure of MV feeders in outage we can roughly estimate that about ½ of the Pirkamaa region and most of “Päijät-Häme” were affected, together that is ~14500/2 + 6200 = 13450 km^2 or 27% of the VFV area. This gives an area Peak-to-Average non-uniformity factor of 0.65*49000/13450 = 2.37.

Hourly peak fault frequency, within affected area, during Sylvi storm					
	Urban	Suburban	Rural	Total	
Peak-to-Average Event Rate (area) PAER_area	2.37	2.37	2.37		
Peak-to-Average Event Rate (time and area) PAER_time_area	1021.2	1021.2	1021.2		
peak MV faults / h	3.06	9.55	372.09	384.69	f / h

During the worst hour of Sylvi the Peak-to-Average Event (=fault) Rate increased in the storm affected area by a factor of ~1000 compared to the yearly average.

These values for MV fault frequencies and Peak-to-Average Event Rates (PAER) will be used in the subsequent sections to derive proportional communication event rates, i.e. for those events which are triggered by a fault (alarms, tele-control).

4.2.3 Fault frequencies (LV, MV broken connector)

All MV faults are assumed to follow the Peak-to-Average Event Rates (PAER) established in the previous section.

LV faults: Around 1200 or ~30% of the LV faults occurred during the storms, out of a total around 4000 / a. Similarly to the last section point B. we assume, that of these 1200 faults around 0.57*0.5*0.9 = ~26 % occurred during Sylvi's most destructive hour, i.e. ~307 faults / h. The dominating LV fault is one phase missing.

The average and Sylvi 'busy-hour' fault frequencies and their corresponding Peak-to-Average Event Rates (PAER) are summarized as follows:

Yearly average fault frequency (2010)	% of MV faults	Urban	Suburban	Rural	Total	
Customer outage notice	220	57.7	180.2	7021.9	**7259.7**	f / a
LV zero conductor fault	12	3.1	9.8	383.0	**396.0**	f / a
LV one phase missing	125	32.8	102.4	3989.7	**4124.8**	f / a
LV voltage level	5	1.3	4.1	159.6	**165.0**	f / a
MV broken conductor	1.5	0.4	1.2	47.9	**49.5**	f / a
MV remaining faults	98.5	25.8	80.7	3143.9	**3250.4**	f / a

Hourly peak fault frequency, within whole system area, during Sylvi storm	Urban	Suburban	Rural	Total		PAER_time	PAER_area
Customer outage notice	4.4	13.9	540.3	**558.6**	f / h	674.1	2.4
LV zero conductor fault	0.2	0.8	29.5	**30.5**	f / h	674.1	2.4
LV one phase missing	2.5	7.9	307.0	**317.4**	f / h	674.1	2.4
LV voltage level	1.50E-04	4.67E-04	1.82E-02	**1.88E-02**	f / h	1.0	1.0
MV broken conductor	0.0	0.1	2.4	**2.4**	f / h	430.9	2.4
MV remaining faults	1.3	4.0	154.6	**159.9**	f / h	430.9	2.4

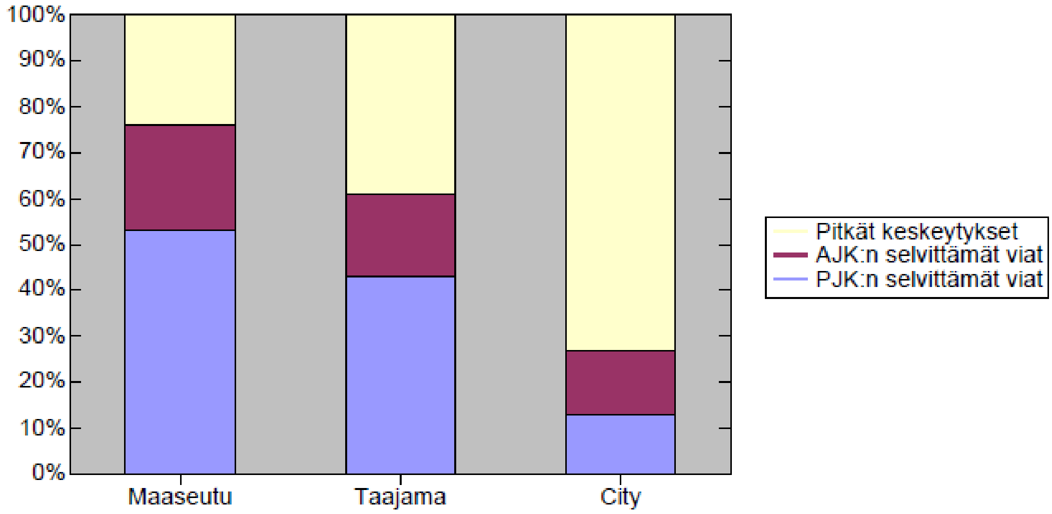
4.2.4 Reclosing

Intermittent faults cleared by reclosing are not included in the above MV (permanent) fault frequencies; however, they do cause communications events such as fault current alarms and switching state indications.

The following statistics from [11] connects reclosing events to permanent faults:

7.1 Pika- ja aikajälleenkytkentöjen selvittämät viat kaikista vikakeskeytyksistä

	Maaseutu	Taajama	City
PJK:n selvittämät viat	53%	43%	13%
AJK:n selvittämät viat	23%	18%	14%
Pitkät keskeytykset	24%	39%	73%



Reclosers can be located on poles along the feeder or at the HV/MV substation. As the communication media and routes may differ, we distinguish both cases. Reclosing along the feeder is proportional to (# of reclosers / # of MV feeders).

The detailed assumptions, together with the triggered events are as follows:

Table 4.2.4-1

Reclosing and Fault Isolation		Urban	Suburban	Rural	Total			Remarks
		Statistics 2010						from ET
successful HSR		0.13	0.43	0.53		%		
successful DR		0.14	0.18	0.23		%		
permanent faults		0.73	0.39	0.24		%		
		Reclosing events						
HSR		**35.0**	**175.2**	**8819.5**	**9029.7**	f / a		3 alarms (OC + open + close)
along feeder (pole mounted)		0.0	40.4	1413.4	**1453.8**	f / a		
at HV/MV substation		35.0	134.8	7406.1	**7575.9**	f / a		
DR		**30.5**	**99.9**	**4145.1**	**4275.5**	f / a		3 alarms (OC + open + close)
along feeder (pole mounted)		0.0	23.0	664.3	**687.3**	f / a		
at HV/MV substation		30.5	76.8	3480.9	**3588.2**	f / a		
unsuccessful DR		**26.2**	**81.9**	**3191.8**	**3299.9**	f / a		2 alarms (OC + open)
along feeder (pole mounted)		0.0	18.9	511.5	**530.4**	f / a		
at HV/MV substation		26.2	63.0	2680.3	**2769.5**	f / a		
Permanent faults. Isolation with r.c. disconnectors		26.2	81.9	3191.8	**3299.9**	f / a		5 retries: 5*2=10 disconnector cmd + 5 recl cmd + 4 recl alarm + N.O. close cmd; total of 20 events

4.3 Synopsis of the selected use cases

In a first version of this report only today's use cases such as AMR, use of AMR alarms in DMS for MV/LV outage management and MV feeder automation are considered. This will establish a baseline scenario which can be verified against empirical data obtained from current communication arrangements.

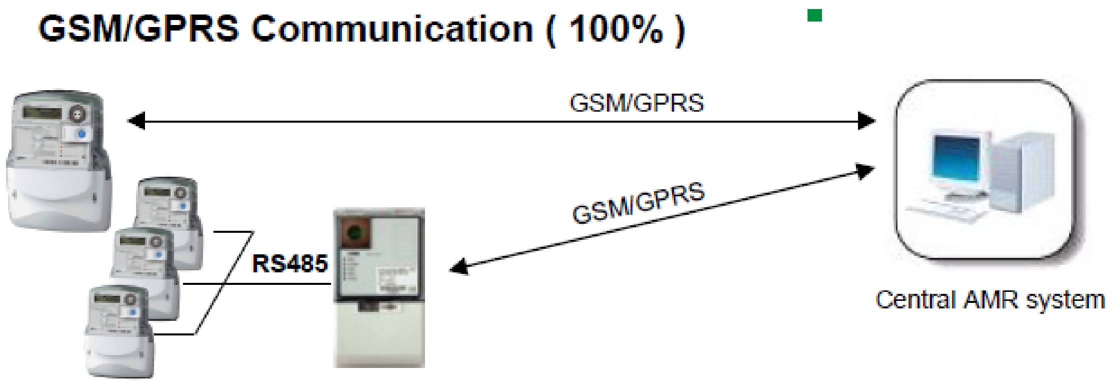
In a revised version of this report more speculative SG use cases will be added which could materialize around 2020 such as more advanced distribution automation concepts, secondary substation automation, DR, etc.

Detailed event frequencies and volumetric information will be provided in later sections for the following use cases:

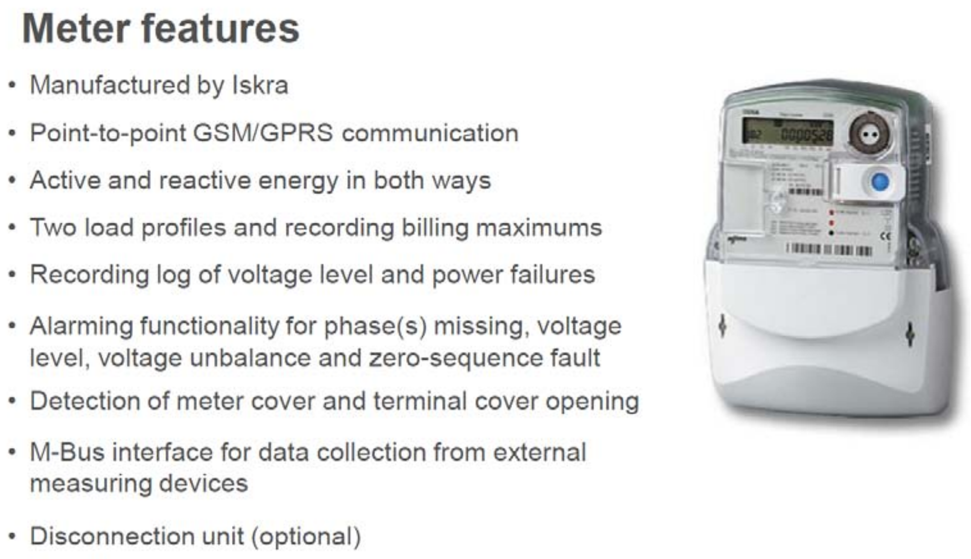
4.3.1 AMR

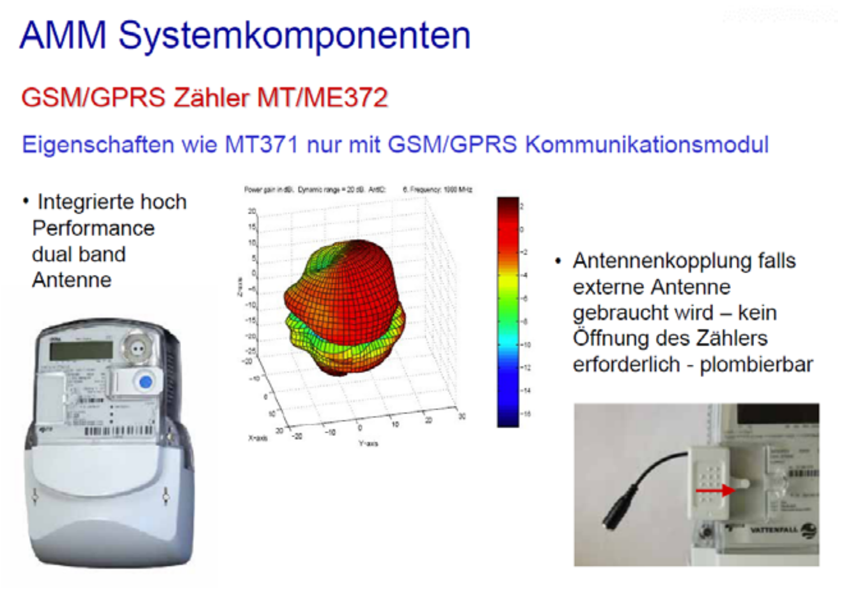
The assumed metering case is one with 100% cellular connectivity. That would be via GPRS900 today, but in the related SGEM studies LTE is assumed.

Some of the urban and suburban meters are behind a RS485 'concentrator' which we assume a 'dumb' device merely relaying the meter traffic. Nevertheless, the meter activity may be configured (coordinated) in order to bundle activity (sending reads, alarms,..) into a common RRC session. This will, however, not affect the traffic volumes which are assumed to be proportional to the amount of meters.



Additional information regarding the meters can be found from [7,14,15,16].

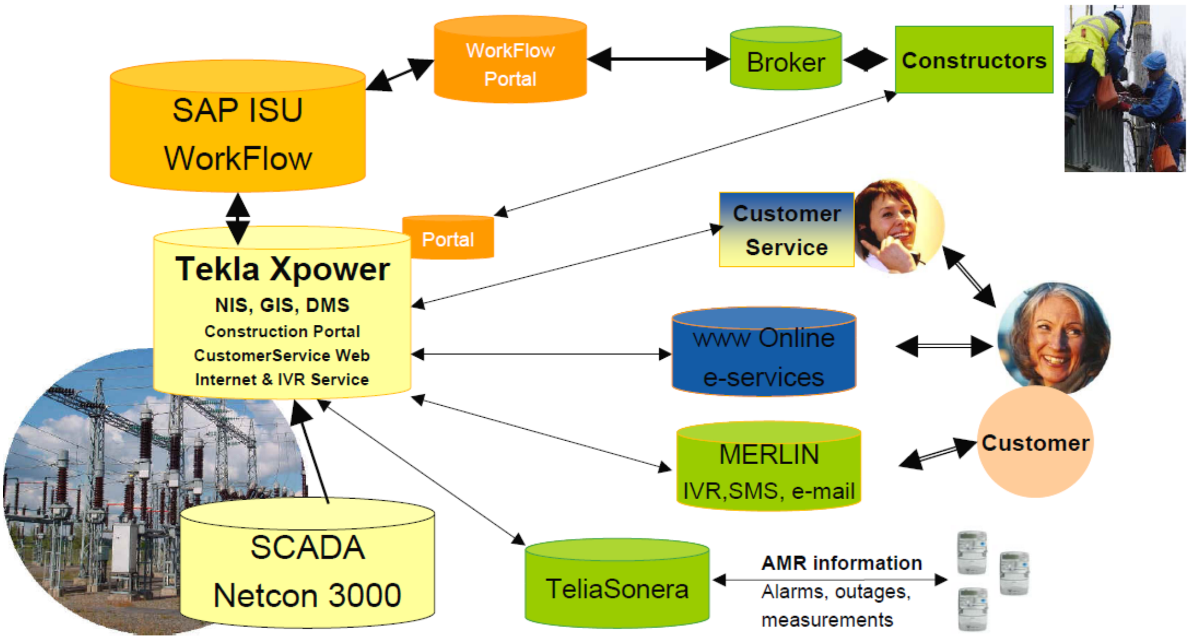




4.3.2 LV, MV Outage management with AMR + DMS

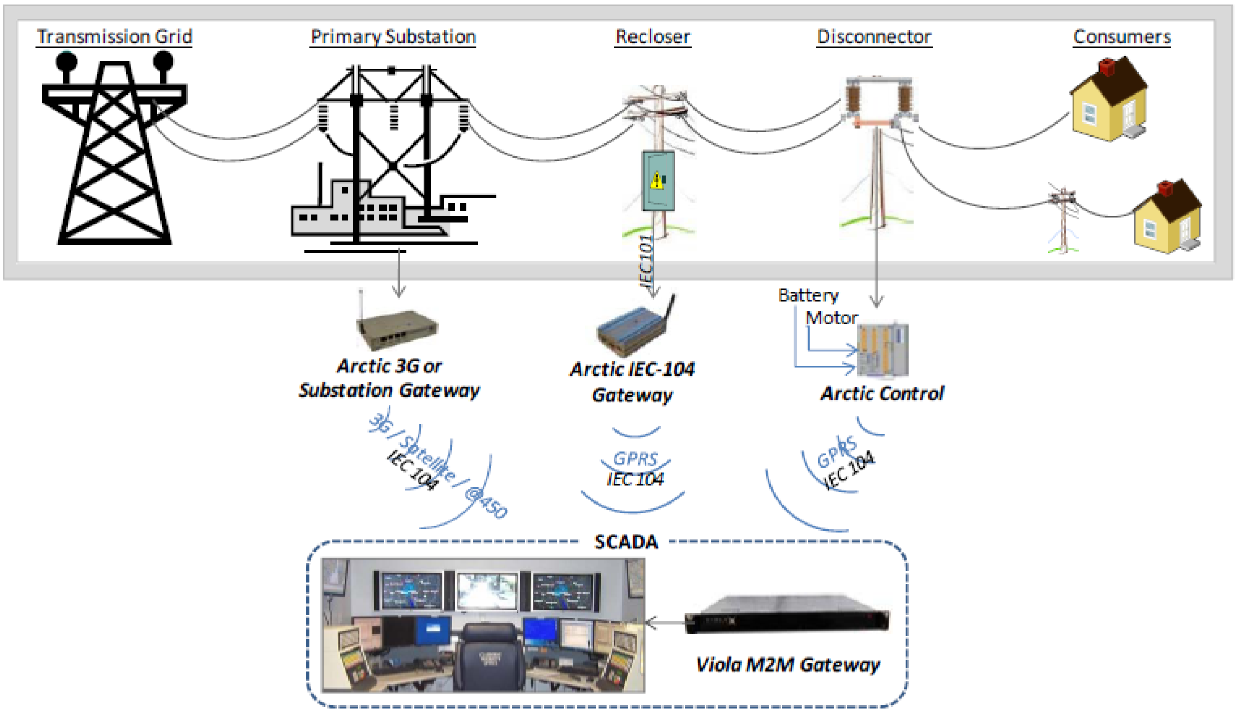
In this use case meters provide alarms to DMS as per the following architecture (see [6,7,8]).

The use of meter alarms and queries are described in fairly good detail in [12] from a DMS perspective.



4.3.3 MV Feeder Automation (FA)

A synopsis of the considered distribution (feeder) automation use cases can be found from [17] from which the following figures are borrowed:



Network Position	Viola Systems Product	Number of Devices	Functionality
SCADA	Viola M2M Gateway Enterprise Edition	3	*Provides fixed IP addresses to all Arctic devices enabling two-way operation, as well as remote maintenance control via a VPN tunnel*
Primary substations	Arctic 3G Gateway and Arctic Substation Gateway	130	*Provides high communication capacity and availability with backup routing function*
Reclosers	Arctic IEC-104 Gateway	200	*Offers real-time remote control and monitoring, thus enabling fast fault isolation and efficient recovery from blackouts*
Disconnector stations	Arctic Control	1300	*Provides a total solution for disconnector control including motor protection, battery charging and monitoring as well heater control*

4.4 Event frequencies and data volume requirements of selected use cases

The list of considered events is not intended to be complete; the focus is on events which either cause a significant baseload (e.g. meter reads, RTU pings) or are triggered by faults and thus scale with high Peak-to-Average factors during storms or communication equipment outages.

It is expected that some additions and corrections of the event related parameters are needed in order to calibrate the scenario against actual communication volumes. For example, events related to outages of the VPN connections (PDP context timer expiry, changeover from M2M GWs, IEC-104 General Interrogations, VPN connection parameter re-negotiations,…) are not yet worked out. The same applies for failures of the telco equipment itself (eNB, EPC, M2M GW,…) which lead to a larger number of connection re-establishment requests of the field devices within short periods of time. These additions will be provided in a corrected version of this report as part of the analysis work around D6.1.3.

4.4.1 Mapping of Faults to Events, Event frequencies

A number of events scale with fault frequencies, however, not all of them such as pings. The rationale for event frequencies is captured in the ‘Remark’ column. The recloser related IEC-104 events are accumulated from the # of alarms and commands as provided in Table 4.2.4-1.

The current assumptions regarding the list of events and their frequencies are captured in Table 4.4.1-1. Also the Peak-to-Average Event Rates (PAER) multipliers for computing event rates under storm conditions are provided.

Table 4.4.1-1

				Urban	Suburban	Rural	Total			
Events & frequencies	Use cas	Field devi	UL/DL triggered	Events / a	Events / a	Events / a	Events / a	Remarks	PAER_tim	PAER_are
AM reads	AMR	AM	UL	1.899E+07	3.072E+07	9.378E+07	1.435E+08	AM reads uniformly over 8 h, spatially uniform	3.0	1.0
Alarm zero conductor fault	AMR+DMS	AM	UL	29.0	60.6	775.6	8.652E+02	1/2 of the AM on LV feeder send alarm	674.1	2.4
AM query	AMR+DMS	AM	DL	29.0	60.6	775.6	8.652E+02	the other half is queried after zero conductor fault alarm	674.1	2.4
Alarm one phase missing	AMR+DMS	AM	UL	302.2	631.1	8079.1	9.012E+03	1/2 of the AM on LV feeder send alarm	674.1	2.4
AM query	AMR+DMS	AM	DL	302.2	631.1	8079.1	9.012E+03	the other half is queried after one phase missing alarm	674.1	2.4
Alarm voltage level	AMR+DMS	AM	UL	65.5	265.1	6571.0	6.902E+03	1/10 of the AM on MV feeder send alarm	1.0	1.0
Alarm voltage unbalance	AMR+DMS	AM	UL	88.5	357.9	8870.9	9.317E+03	1/2 of the AM on MV feeder send alarm	430.9	2.4
AM query	AMR+DMS	AM	DL	726.3	2937.4	72815.3	7.648E+04	6.25% of AM on MV feeder are queried after MV fault. During storm repairs time are stretched over 24 h	18.0	2.4
AM query	AMR+DMS	AM	DL	957.4	1999.5	25594.7	2.855E+04	90% of AM on the same LV feeder are queried after customer outage notice	674.1	2.4
IEC-104 Event	FA	Recloser	UL	0.0	555.9	20023.0	2.058E+04	see description 'Reclosing events'	430.9	2.4
IEC-104 Command + Reply	FA	Recloser	DL	0.0	409.5	15958.8	1.637E+04	see description 'Reclosing events'	430.9	2.4
IEC-104 Event	FA	Disconnector	UL	0.0	0.0	0.0	0.000E+00	TBD;reserved	430.9	2.4
IEC-104 Command + Reply	FA	Disconnector	DL	288.3	900.9	35109.4	3.630E+04	see description 'Reclosing events'	430.9	2.4
Ping	FA	Recloser	DL	0.000E+00	1.603E+07	5.344E+07	6.947E+07	ICMP echo req, 1 per minute + 1 per h	1.0	1.0
Ping	FA	Disconnector	DL	1.069E+07	1.603E+08	7.214E+08	8.924E+08	ICMP echo req, 1 per minute + 1 per h	1.0	1.0
IEC-104 General Interrogation	FA	Recloser	DL	0.0	0.0	0.0	0.000E+00	TBD; report all process values after connection re-establishment	1.0	1.0
IEC-104 General Interrogation	FA	Disconnector	DL	0.0	0.0	0.0	0.000E+00	TBD; report all process values after connection re-establishment	1.0	1.0
HV/MV substation measurements	SS_CONN	GW_SS	UL	0.0	0.0	0.0	0.000E+00	TBD	1.0	1.0
IEC-104 Event	SS_CONN	GW_SS	UL	353.8	1088.5	50788.4	5.223E+04	see description 'Reclosing events'	430.9	2.4
IEC-104 Command + Reply	SS_CONN	GW_SS	DL	131.0	409.5	15958.8	1.650E+04	see description 'Reclosing events'	430.9	2.4
Ping	SS_CONN	GW_SS	DL	1.603E+06	4.809E+06	5.557E+07	6.199E+07	ICMP echo req, 1 per minute + 1 per h	1.0	1.0
Total / a				3.128E+07	2.119E+08	9.244E+08	1.168E+09			
Total / h				3570.9	24186.5	105530.3	133287.7			
Total / s				0.99	6.72	29.31	37.02			

4.4.2 Event communication volumetric data

The current assumptions regarding the event communication volumetric data are captured in Table 4.4.2-1.

Table 4.4.2-1

TCP/IP and 3GPP protocol overhead parameters		
IP MTU	1400	Bytes
IP+TCP,UDP headers	42	Bytes
TCP/IP connection establishment overhead	500	Bytes
VPN overhead	69	Bytes
fixed TCP/IP transmission overhead	0	Bytes
LTE PDCP + RLC overhead factor	1.03	

Events & volumetrics	Use case	Field device	UL/DL triggered	UL Application payload [Bytes]	DL Application payload [Bytes]	UL Payload incl. protocol overheads [Bytes]	DL Payload incl. protocol overheads [Bytes]
AM reads	AMR	AM	UL	9600	25	10705.8	843.6
Alarm zero conductor fault	AMR+DMS	AM	UL	300	25	867.3	584.0
AM query	AMR+DMS	AM	DL	300	25	867.3	584.0
Alarm one phase missing	AMR+DMS	AM	UL	300	25	867.3	584.0
AM query	AMR+DMS	AM	DL	300	25	867.3	584.0
Alarm voltage level	AMR+DMS	AM	UL	300	25	867.3	584.0
Alarm voltage unbalance	AMR+DMS	AM	UL	300	25	867.3	584.0
AM query	AMR+DMS	AM	DL	300	25	867.3	584.0
AM query	AMR+DMS	AM	DL	300	25	867.3	584.0
IEC-104 Event	FA	Recloser	UL	450	0	577.8	114.3
IEC-104 Command + Reply	FA	Recloser	DL	450	50	577.8	165.8
IEC-104 Event	FA	Disconnector	UL	450	0	577.8	114.3
IEC-104 Command + Reply	FA	Disconnector	DL	450	50	577.8	165.8
Ping	FA	Recloser	DL			84	84
Ping	FA	Disconnector	DL			84	84
IEC-104 General Interrogation	FA	Recloser	DL	0	0	0.0	0.0
IEC-104 General Interrogation	FA	Disconnector	DL	0	0	0.0	0.0
HV/MV substation measurements	SS_CONN	GW_SS	UL	0	0	0.0	0.0
IEC-104 Event	SS_CONN	GW_SS	UL	450	0	577.8	114.3
IEC-104 Command + Reply	SS_CONN	GW_SS	DL	450	50	577.8	165.8
Ping	SS_CONN	GW_SS	DL			84	84

4.5 Wireless communications system parameters

4.5.1 General assumptions

In subsequent studies within this SGEM subtask, the SG communications traffic with field devices (automatic meters, RTUs,…) is assumed to be carried exclusively wirelessly. In Europe wireless traffic from FANs is collected today pre-dominantly by public GSM900 networks. This is also the case in the above Vattenfall / Finland distribution system scenario.

M2M traffic carried today by public GSM900 networks will be shared in the nearer future with WCDMA/HSPA 2100/900 networks and in the more distant future additionally with LTE800/1800/2600 networks. Some of these networks will be implemented by CSPs with multi-radio / standard base stations serving different 3GPP radios within or across their respective frequency bands. They are built on a generic ("SW defined radio") base station and common core network platform. This 3GPP radio evolution is described in more detail in [1].

LTE has established itself in the CSP domain as the leading global standard and platform for IP optimized radio communications. All major mobile standards such as GSM, WCDMA and cdma2000 converge into the LTE IP based platform.

Also established radio standards for mission critical applications such as TETRA (for public safety), GSM-R (for life-critical train-control and railway communications) and P25 (for public safety in the US) evolve their next generation standard towards LTE/SAE. As a case in point, within the US, a strong consensus has emerged in support of LTE/SAE, as a common technology platform for the public safety broadband network. Subsequently the FCC will mandate that all networks deployed in the 700 MHz public safety broadband spectrum adopt LTE in order to facilitate nationwide interoperability for public safety broadband networks.

Therefore, there is an opportunity for utilities to join this growing ecosystem for mission critical radios based on LTE. Some utilities, notably in US, are expected migrating their current dedicated radio networks to a dedicated converged LTE IP network.

From this perspective it may be of interest within the coming FP3 of SGEM to conduct comparative studies on OPEX/CAPEX of a CSP provided vs. dedicated utility radio network. By assuming LTE in both cases we don't need to additionally translate assumptions and results across different radio technologies.

Therefore we consider for the following communications system parameters both a *CSP provided LTE MBB network* as well as a *Dedicated LTE network* which has been coverage optimized for the utility.

In order to simplify the subsequent analysis and focus on the worst case from a loading / congestion point of view we assume in both cases that all SG traffic is aggregated into a single LTE network and frequency band. This also fits to the timeframe (up to 2020) of the considered distribution automation use cases. By 2020 CSP operated LTE networks will be more mature and can take a larger burden of the MBB and utility M2M traffic.

For the dedicated utility optimized LTE network it is interesting to know how much of the LTE capacity will be used up by the SG M2M traffic (or the other way around: how much spectrum would actually be required by the utility), the potential for congestion and OPEX/CAPEX comparisons with M2M services from CSP MBB networks.

Even though LTE is chosen in the analysis, many of the results should nevertheless also hold for comparable broadband radios such as CSP operated HSPA or utility operated WiMAX.

The following general system parameters will be assumed:

LTE system parameters			
Duplex mode	FDD		
Channel BW	10	MHz	
MIMO settings	1TX - 2RX		UL, DL

4.5.2 Frequency bands

When LTE is operated as dedicated network, the utility would need to have access to a licensed frequency band, either directly or on a leased basis. The licensed spectrum can be either a paired or unpaired band, as LTE supports both, the FDD and TDD duplex modes of operation. Paired frequencies within the propagation and interference friendly licensed bands below 1 GHz are particularly attractive for LTE deployment.

Some countries, for example Canada have already designated spectrum @1.8 GHz to utilities for broadband communications, in other countries the regulators have still to make decisions. Utilities, notably in the US, might be interested in obtaining direct access to spectrum @700 MHz or by establishing partnerships with other stakeholders using LTE in the Public Safety and Critical Infrastructure space. In some countries, e.g. Australia, spectrum has been provided to utilities on a lease basis in order to facilitate wireless connections of meters.

In subsequent studies of this SGEM subtask we will use the 900 MHz[1] and close by 800 MHz[2] bands in order to ease relative comparisons without the need to worry about the large impact from propagation related phenomena across frequency bands. Bands <1 GHz help also in so far as they connect to the available data from the numerous GSM900 automation use cases of today. While the 900 MHz band is not a typical band for public LTE, it is used for WCDMA900 in Finland and the close by 800 MHz is used on other countries for LTE, e.g. Germany, see [1].

It must be remembered, that currently utilities don't have access to licensed broadband spectrum in Europe, in particular not to the 800 MHz band. The spectrum related situation in Europe is summarized in [3] from an EUTC perspective. An interesting topic for subsequent SGEM studies is evaluating the potential benefits and required amount of broadband spectrum licensed to utilities in Europe.

4.5.3 Radio link budgets

Following the utility scenario definition the next step in traffic dimensioning according to the methodology of Fig. 3-1 is estimating LTE cell sizes. Two cases for LTE network deployment are considered in the following radio link budget (RLB) analysis:

1. <u>CSP provided LTE900 MBB network</u>: the radio network is dimensioned for public MBB traffic and is compatible with an existing GSM900 site grid. SG M2M traffic, e.g. from AM locations will be picked up 'as is' without any impact on the radio network design (e.g. cell range).
2. <u>Dedicated LTE800 network which is coverage optimized for the utility</u>: here the field device RF site parameters (i.e. use of external antennas with meters) and cell design (range, RF site parameters) is optimized for the SG use case requirements only – this is done in order to minimize the number of required LTE sites. There is no existing 2G site grid and we can thus freely 'stretch' the sites in line with the SG traffic requirements in order to maximize radio coverage and keep investment costs low. With only M2M traffic present we don't need to worry about high (say 384 kbps) broadband bit rate user requirement at the cell edge

[1] LTE Band 8

[2] LTE Band 20, not yet licensed in Finland

and can instead design for lower data rates. The network can be designed solely for coverage and need not be made denser due to capacity. The cell edge design is set by providing coverage to meters and this will also cover for the RTUs.

Also the respective site counts for the VFV service area are provided.

Background material on LTE radio link budgets can be found from [2].

4.5.3.1 CSP provided LTE MBB network

	UL center frequency [MHz]	897.5			Band 8
	Link budget	**Urban**	**Suburban**	**Rural**	
	Uplink	**LTE**	**LTE**	**LTE**	
	Data rate [kbps]	**64**	**64**	**64**	
	Transmitter - RTU				
a	Max tx power [dBm]	23.0	23.0	23.0	
b	Tx antenna gain [dBi]	-2.0	-2.0	-2.0	USB stick with integrated antenna
c	Body loss [dB]	0.0	0.0	0.0	
d	EIRP [dBm]	**21.0**	**21.0**	**21.0**	=a+b-c
	Receiver - eNode B				
e	Node B noise figure [dB]	2.5	2.5	2.5	
f	Thermal noise [dBm]	-118.4	-118.4	-118.4	=k(Boltzmann)*T(290K)*B. Note 1
g	Receiver noise floor [dBm]	-115.9	-115.9	-115.9	=e+f
h	SINR [dB]	-4.8	-4.8	-4.8	Stationary RTU. Note 2
i	Receiver sensitivity [dBm]	-120.7	-120.7	-120.7	=g+h
j	Interference margin [dB]	3.0	3.0	3.0	Note 3
k	Cable loss [dB]	0.4	0.4	0.4	Note 4
l	Rx antenna gain [dBi]	15.5	16.5	17.0	
	Maximum path loss	**153.8**	**154.8**	**155.3**	=d-i-j-k+l

Note 1: B = noise bandwidth : LTE 2 PRB = 360 kHz
Note 2: 2-rx eNode B assumed, fast fading margin included
Note 3: low ... moderate load assumed
Note 4: Feederless site, tower top RF

	Link budget	**Urban**	**Suburban**	**Rural**	
	Downlink	**LTE**	**LTE**	**LTE**	
	Data rate [kbps]	**1024**	**1024**	**1024**	
	Transmitter - eNode B				
a	Tx power [dBm]	46.0	46.0	46.0	
b	Tx antenna gain [dBi]	15.5	16.5	17.0	
c	Cable loss [dB]	0.4	0.4	0.4	
d	EIRP [dBm]	**61.1**	**62.1**	**62.6**	=a+b-c
	Receiver - RTU				
e	UE noise figure [dB]	7.0	7.0	7.0	
f	Thermal noise [dBm]	-104.5	-104.5	-104.5	=k (Boltzmann)*T(290K)*B, Note 1
g	Receiver noise floor [dBm]	-97.5	-97.5	-97.5	=e+f
h	SINR [dB]	-9.0	-9.0	-9.0	From simulations. Note 2
i	Receiver sensitivity [dBm]	-106.5	-106.5	-106.5	=g+h. Note 2
j	Interference margin [dB]	4.0	4.0	4.0	Note 3
k	Control channel overhead [%]	20.0 %	20.0 %	20.0 %	
l	Rx antenna gain [dBi]	-2.0	-2.0	-2.0	
m	Body loss [dB]	0.0	0.0	0.0	Body loss for voice terminal 3 dB
	Maximum path loss	**160.6**	**161.6**	**162.1**	=d-i-j-k+l-m

Note 1: B = noise bandwidth : LTE 50 PRB = 9 MHz
Note 2: 2-rx terminal assumed
Note 3: See Holma et al. p. 225

	Urban	Suburban	Rural	
eNode B antenna height [m]	30	30	50	
RTU antenna height [m]	1.5	1.5	1.5	
Location probability	95.0 %	95.0 %	95.0 %	high end NW
Slow fading standard deviation [dB]	12.0	10.0	9.0	
Indoor loss [dB]	17	13	13	high end NW
Slow fading margin [dB]	14.8	11.7	10.3	
Gain against shadowing [dB]	2.5	2.5	1.9	
Max path loss w/o clutter [dB]	153.8	154.8	155.3	
Max path loss with clutter [dB]	124.6	132.6	134.0	
Correction factor [dB]	0	-6	-17	
Okumura-Hata cell range for 3-sector sites				
			#NUM!	PL for R>20 km
Cell range [km]	**0.89**	**2.22**	**6.60**	
ISD [km]	1.33	3.34	9.90	
Cell area [km^2]	0.51	3.21	28.28	
Site area [km^2]	**1.54**	**9.64**	**84.84**	
Site count for utility area				
	Urban	**Suburban**	**Rural**	**Total**
Area [km^2]	94.1	1147.2	47758.7	49000
Required sites (for coverage)	**62**	**120**	**563**	**745**

4.5.3.2 Dedicated network optimized for utility

	UL center frequency [MHz]	**847**			Band 20
	Link budget	**Urban**	**Suburban**	**Rural**	
	Uplink	**LTE**	**LTE**	**LTE**	
	Data rate [kbps]	**16**	**16**	**16**	
	Transmitter - RTU				
a	Max tx power [dBm]	23.0	23.0	23.0	
b	Tx antenna gain [dBi]	2.0	2.0	2.0	AMR with external antenna, incl. cable loss
c	Body loss [dB]	0.0	0.0	0.0	
d	EIRP [dBm]	**25.0**	**25.0**	**25.0**	=a+b-c
	Receiver - eNode B				
e	Node B noise figure [dB]	2.5	2.5	2.5	
f	Thermal noise [dBm]	-118.4	-118.4	-118.4	=k(Boltzmann)*T(290K)*B. Note 1
g	Receiver noise floor [dBm]	-115.9	-115.9	-115.9	=e+f
h	SINR [dB]	-6.2	-6.2	-6.2	Stationary RTU. Note 2
i	Receiver sensitivity [dBm]	-122.1	-122.1	-122.1	=g+h
j	Interference margin [dB]	1.0	1.0	1.0	Note 3
k	Cable loss [dB]	0.4	0.4	0.4	Note 4
l	Rx antenna gain [dBi]	15.5	16.5	17.5	
	Maximum path loss	**161.2**	**162.2**	**163.2**	=d-i-j-k+l

Note 1: B = noise bandwidth : LTE 2 PRB = 360 kHz
Note 2: 2-rx eNode B assumed, fast fading margin included
Note 3: low load assumed
Note 4: Feederless site, tower top RF

	Link budget	**Urban**	**Suburban**	**Rural**	
	Downlink	**LTE**	**LTE**	**LTE**	
	Data rate [kbps]	**1024**	**1024**	**1024**	
	Transmitter - eNode B				
a	Tx power [dBm]	46.0	46.0	46.0	
b	Tx antenna gain [dBi]	15.5	16.5	17.5	
c	Cable loss [dB]	0.4	0.4	0.4	
d	EIRP [dBm]	**61.1**	**62.1**	**63.1**	=a+b-c
	Receiver - RTU				
e	UE noise figure [dB]	7.0	7.0	7.0	
f	Thermal noise [dBm]	-104.5	-104.5	-104.5	=k (Boltzmann)*T(290K)*B, Note 1
g	Receiver noise floor [dBm]	-97.5	-97.5	-97.5	=e+f
h	SINR [dB]	-9.0	-9.0	-9.0	From simulations. Note 2
i	Receiver sensitivity [dBm]	-106.5	-106.5	-106.5	=g+h. Note 2
j	Interference margin [dB]	4.0	4.0	4.0	Note 3
k	Control channel overhead [%]	20.0 %	20.0 %	20.0 %	
l	Rx antenna gain [dBi]	2.0	2.0	2.0	
m	Body loss [dB]	0.0	0.0	0.0	Body loss for voice terminal 3 dB
	Maximum path loss	**164.6**	**165.6**	**166.6**	=d-i-j-k+l-m

Note 1: B = noise bandwidth : LTE 50 PRB = 9 MHz
Note 2: 2-rx terminal assumed
Note 3: See Holma et al. p. 225

	Urban	Suburban	Rural	
eNode B antenna height [m]	30	30	80	
RTU antenna height [m]	1.5	1.5	1.5	
Location probability	90.0 %	90.0 %	90.0 %	
Slow fading standard deviation [dB]	12.0	10.0	9.0	
Indoor loss [dB]	15	10	8	IPL to meter location
Slow fading margin [dB]	10.1	7.8	6.7	
Gain against shadowing [dB]	2.5	2.5	1.9	
Max path loss w/o clutter [dB]	161.2	162.2	163.2	
Max path loss with clutter [dB]	138.6	146.9	150.5	
Correction factor [dB]	0	-6	-17	
Okumura-Hata cell range for 3-sector sites				
			150.5	PL for R>20 km
Cell range [km]	**2.33**	**5.93**	**27.00**	
ISD [km]	3.49	8.89	40.50	
Cell area [km^2]	3.52	22.83	473.50	
Site area [km^2]	**10.55**	**68.50**	**1420.50**	
Site count for utility area				
	Urban	**Suburban**	**Rural**	**Total**
Area [km^2]	94.1	1147.2	47758.7	49000
Required sites (for coverage)	**9**	**17**	**34**	**60**

4.5.3.3 Observations and comparison

First, it's clear that the UL is the limiting link, mainly due to limited TX power and EIRP of the mobile, respectively field device (meter).

Secondly, the number of required sites for the coverage optimized dedicated LTE800 network is *by a factor of 12 lower* compared to the CSP provided LTE MBB network – 60 sites instead of 745 for the VFV service area scenario. This significant difference is due to the following underlying assumptions in the RF parameters:

- 2 dBi external antenna gain for the meter compared to low mobile device antenna gain ➔ 4 dB difference. For fixed installed meters there are no EIRP limits nor do mobile device SAR limits apply facilitating the use of external antennas. However, there is a cost penalty equipping meters (i.e. those at the cell edge) with external antennas which must be weighted against the cost of additional BS sites.
- UL cell edge bit rate of only 16 kbps vs. 64 kbps ➔ 1.4 dB lower C/I. This lower bit rate is sufficient for M2M connections.
- Less load in the dedicated LTE network with M2M traffic only ➔ 2 dB lower interference margin.
- Sites optimized for coverage only ➔ 80 m masts ➔ better propagation.
- 90% vs. 95% location probability ➔ 3.6 dB less fading margin. Meters don't move and in case of poor coverage, the reception can be permanently improved, e.g. using 5 dBi external antennas or installing the antennas outdoors (at a cost penalty).

- Lower building penetration losses for meter locations than for high quality CSP network aiming at universal coverage, e.g. with row houses meters are often placed outside the house in accessible cabinets with wooden doors ➔ estimated 2 ... 5 dB advantage.
- All in all, these differences accumulate to ~16.5 dB higher allowed maximum path loss (with clutter) for the coverage optimized dedicated LTE utility network.

The RF design and site counts of these two LTE example networks represent the extremes: high quality CSP provided MBB networks in Nordic countries tend to operate with comparable high site densities. On the other hand, the parameters related to the coverage optimization of the dedicated LTE utility network are set on the aggressive side and the resulting cell sizes are likely at the upper limits of what can be achieved in practice. There are also some uncertainties on realistic parameter values for a variety of environments, e.g. those related to building penetration losses for meter locations.

4.5.4 Meters and RTUs per cell

The average amount of meters and RTUs per cell can now be obtained from the information related to the device densities within the utility area (Section 4.1, Table 4.1-1) and LTE cell ranges (Section 4.5.3).

Considerations regarding the variance of device population seen by a cell will be captured in the event related tables (4.4.1).

4.5.4.1 CSP provided LTE MBB network

CSP LTE			
Average # of automatic meters per cell			
	Urban	Suburban	Rural
AM / cell	283.7	235.6	152.1
Average # of RTU per cell			
	Urban	Suburban	Rural
Gateways	0.016	0.025	0.06
Reclosers	0.000	0.084	0.06
Disconnectors	0.109	0.840	0.80

4.5.4.2 Dedicated network optimized for utility

DNW LTE			
Average # of automatic meters per cell			
	Urban	Suburban	Rural
AM / cell	1943.5	1674.8	2547.3
Average # of RTU per cell			
	Urban	Suburban	Rural
Gateways	0.112	0.179	1.03
Reclosers	0.000	0.597	0.99
Disconnectors	0.747	5.971	13.38

4.5.4.3 Observations and comparison

There is significant variation in number of attached meters/RTUs per cell. For example, rural cells of the coverage optimized dedicated LTE utility network are able to pick up ~17x the amount of meters due to their correspondingly larger coverage area. These cells are able to concentrate the generally sparsely distributed SG field devices and their traffic. This also means that they are potentially more vulnerable to overload in presence of SG traffic with very large peak-to-average characteristics (e.g. during power outages / storms).

4.5.5 LTE spectral efficiency (SE)

Yet another step in traffic dimensioning according to the methodology of Fig. 3-1 is to relate the carried SG traffic to the actual LTE cell throughput (i.e. capacity) and to compute the resulting M2M session densities, e.g. for quasi-simultaneous meter reads, alarms etc. For this assumptions on LTE spectral efficiency need to be made.

Background material on the factors impacting LTE spectral efficiency can be found in [2]. In particular, the used MIMO modes (here: no MIMO, instead 1TX, 2-RX) and base station inter-site distance are relevant. In the following tables estimates of the cell specific LTE spectral efficiency are provided which were interpolated from system simulations for given load points. These figures can be seen as relatively conservative estimates for SE, as possible gains from additional LTE capacity features (MIMO, enhanced scheduling options, etc) are not included.

In the last row also the system total air interface capacity (i.e. sum across all cells) is shown.

4.5.5.1 CSP provided LTE MBB network

CSP LTE cell SE				
	Urban	Suburban	Rural	Total
# of cells	186	360	1689	2235
DL - Average SE (homogeneous cell loading)				
25 % load	3845.4	3095.7	2804.8	kbps
50 % load	6713.0	6002.1	5609.6	kbps
70 % load	8763.7	8323.5	7853.4	kbps
DL - Peak SE (heterogeneous cell loading, target cell 100%)				
25 % load	15381.6	12382.8	11219.1	kbps
50 % load	13426.1	12004.2	11219.1	kbps
70 % load	12519.5	11890.6	11219.1	kbps
UL - Average SE (homogeneous cell loading)				
25 % load	2234.1	1563.6	1337.9	kbps
50 % load	3900.1	3031.5	2675.8	kbps
70 % load	5091.5	4204.0	3746.1	kbps
70 % load	2.29	1.89	1.69	GB/h
UL - Peak SE (heterogeneous cell loading, target cell 100%)				
25 % load	8936.4	6254.3	5351.6	kbps
50 % load	7800.2	6063.1	5351.6	kbps
70 % load	7273.6	6005.8	5351.6	kbps
70 % load	3.27	2.70	2.41	GB/h
System total air interface capacity @ 70% load				
DL [Gbps]	1.63	3.00	13.26	**17.89**
UL [Gbps]	0.95	1.51	6.33	**8.79**
DL [GB/h]	733.52	1348.40	5968.95	**8050.87**
UL [GB/h]	426.16	681.05	2847.24	**3954.45**

4.5.5.2 Dedicated network optimized for utility

DNW LTE cell SE				
	Urban	Suburban	Rural	Total
# of cells	27	51	102	180
DL - Average SE (homogeneous cell loading)				
25 % load	3087.6	2810.1	2195.9	kbps
50 % load	5991.3	5616.9	4574.8	kbps
70 % load	8310.6	7862.2	6404.7	kbps
DL - Peak SE (heterogeneous cell loading, target cell 100%)				
25 % load	12350.3	11240.5	9149.6	kbps
50 % load	11982.6	11233.8	9149.6	kbps
70 % load	11872.3	11231.7	9149.6	kbps
UL - Average SE (homogeneous cell loading)				
25 % load	1557.3	1342.0	698.6	kbps
50 % load	3021.8	2682.4	1455.4	kbps
70 % load	4191.5	3754.7	2037.6	kbps
70 % load	1.89	1.69	0.92	GB/h
UL - Peak SE (heterogeneous cell loading, target cell 100%)				
25 % load	6229.0	5368.1	2910.8	kbps
50 % load	6043.5	5364.9	2910.8	kbps
70 % load	5987.9	5363.9	2910.8	kbps
70 % load	2.69	2.41	1.31	GB/h
System total air interface capacity @ 70% load				
DL [Gbps]	0.22	0.40	0.65	**1.28**
UL [Gbps]	0.11	0.19	0.21	**0.51**
DL [GB/h]	100.97	180.44	293.98	**575.39**
UL [GB/h]	50.93	86.17	93.52	**230.62**

4.5.5.3 Observations and comparison

DL capacity is by a factor of 2 … 2.5 larger than UL capacity. With DL MIMO, this imbalance could increase by yet another ~20%. On the other hand, a much larger portion of the SG traffic is expected on the UL (field device ➔ SCADA/DMS) which indicates that LTE TDD might be an interesting alternative as dedicated utility NW to match these needs.

The so called “coverage vs. capacity trade-off” can also be observed from these figures. Due to large cells sizes and lower fading and interference margins the coverage optimized dedicated LTE utility network operates close to the “thermal noise limit”. This means that the field devices operate relatively more often at their TX power limits and cannot use spectrally more efficient modulation and coding schemes. For example, only 54% of the UL cell capacity of the CSP operated LTE network is reached.

These figures also show that the CSP operated much denser LTE network possess ~17x the aggregate UL air interface capacity for the same area, mainly due to the much larger number of sites.

4.5.6 Observations and Suggestions

Compared to the CSP operated dense LTE network, the stretched cells of the coverage optimized dedicated LTE utility network concentrate SG field devices and their traffic by a factor of ~16. At the same time their spectral efficiency can be lower by a factor of ~2 (on the UL). This means that they are potentially more vulnerable to overload in presence of SG traffic with very large peak-to-average characteristics (e.g. during power outages / storms).

Therefore it is proposed to start in the subsequent LTE network dimensioning studies with this worst case first.

5 Conclusions

This report defined the detailed power and communications system scenario data which will be used in subsequent LTE network dimensioning studies. The scenario data has been derived from the topology of the Vattenfall / Finland distribution system network assuming LTE wireless communications.

Communications requirements have been considered for today's use cases such as AMR, use of AMR alarms in DMS for MV/LV outage management, MV feeder automation. It is expected that some additions and corrections of the event related parameters are needed in order to calibrate the scenario against actual communication volumes. These will be provided in a corrected version of this report as part of the analysis work around D6.1.3.

In a revised version of this report more speculative SG use cases will be added which could materialize around 2020 such as more advanced distribution automation concepts, secondary substation automation, DR, etc.

6 Abbreviations

7 References

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