AUTOMATIC METER READING COMMUNICATION AND POSSIBILITIES IN ELECTRICITY DISTRIBUTION AUTOMATION

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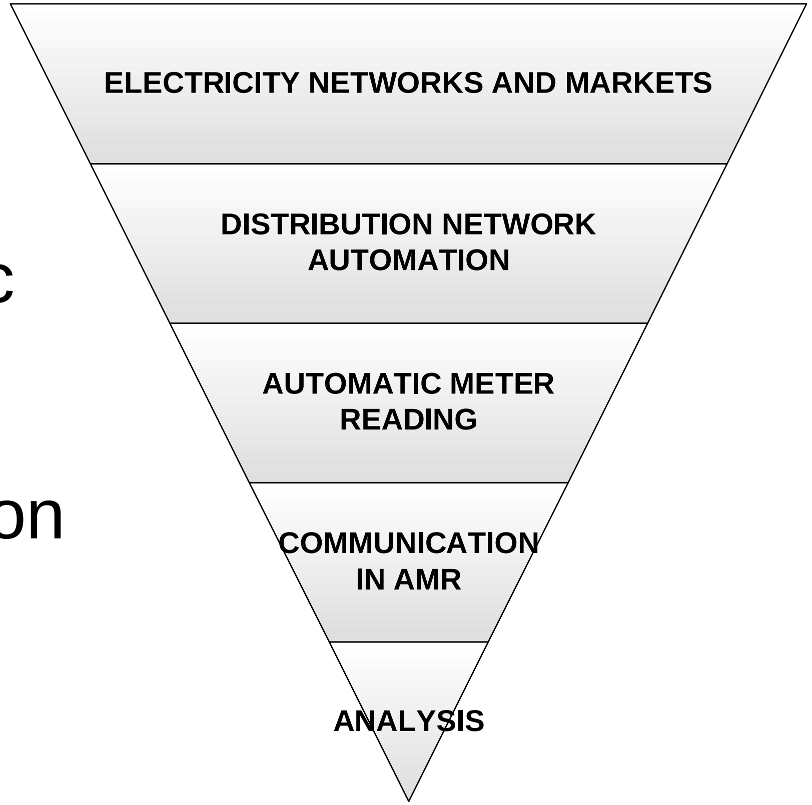
Structure of the Presentation



- Introduction of the Thesis' Topic
- Electricity Market and Metering
- Electricity Distribution Automation
- Automatic Meter Reading
- Communication Technologies
- Communication Technology Comparison Criteria
- Communication Technology Analyses
- Results and Conclusions

The Objectives of the Thesis

- (1) the specification of AMR meter-originated event and quality data and its existing and/or potential utilization in the distribution network management, and
- (2) the examination of the suitability of AMR communication technologies to a large-scale meter reading and event-based communication.

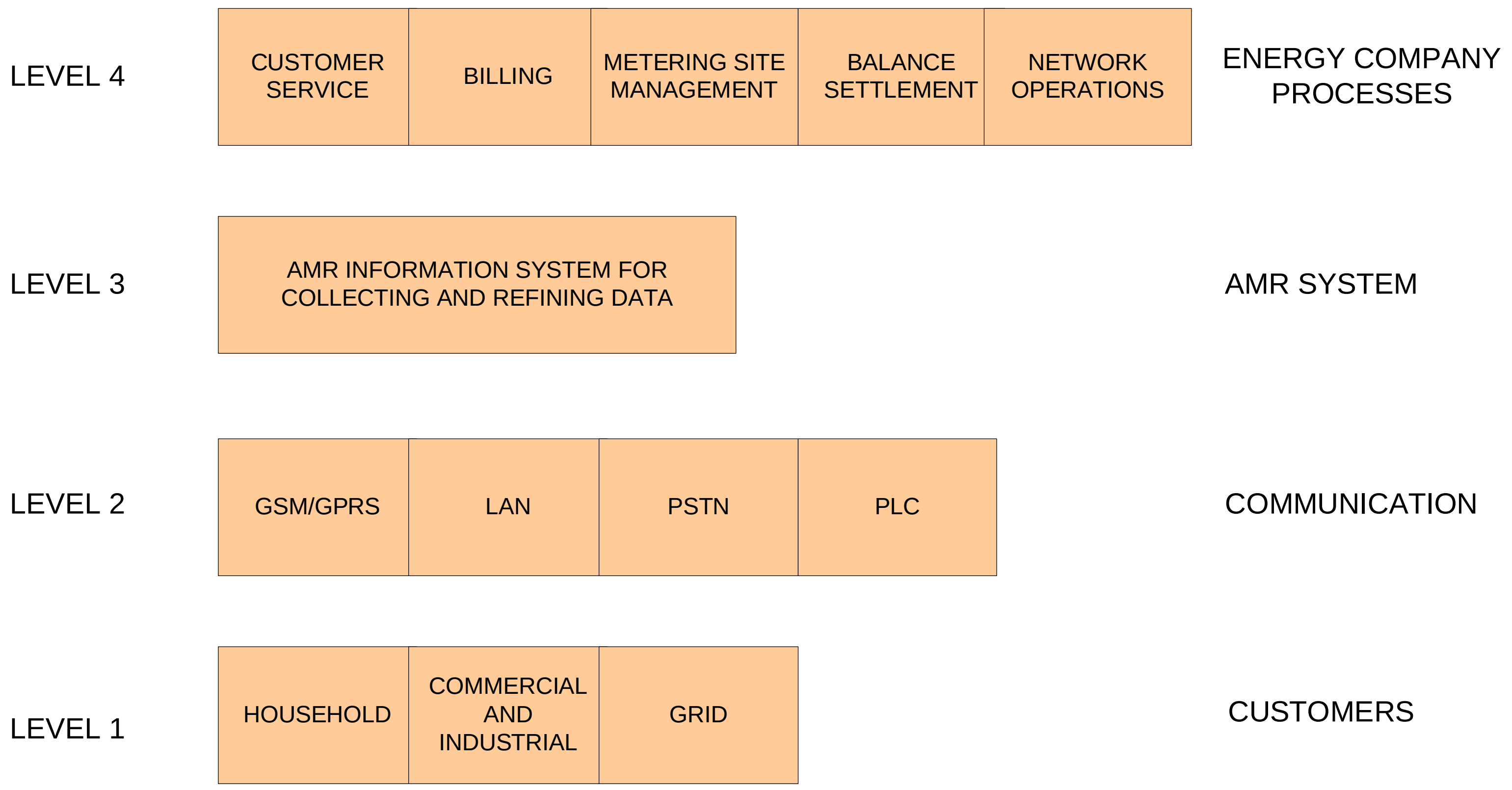
The Methodology of the Thesis

- (1) Interviews of key stakeholders to obtain future possibilities of the usage of AMR data in electricity distribution automation
- (2) Case studies of the congestion in different telecommunication networks caused by event transmission caused by alarms of outages or disturbances

What is AMR: Meters

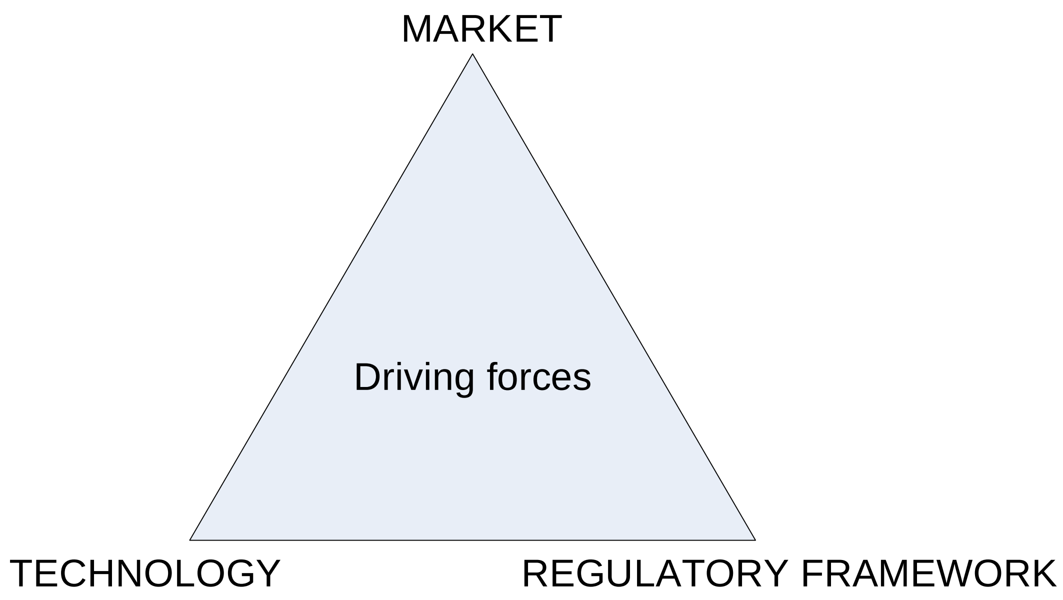
- From electromechanical energy meters to fully electronic energy meters
- New electronic meters include advanced functions and are connected to related information systems

What is AMR: System



- An AMR System consists of four levels
  - Meters, Communication, AMR system, Energy Company Processes

What drives us toward AMR



(1) Regulation: E.g. Sweden

(2) Technological development:Communication technologies and electrical meters

(3) Market Changes: Energy Market Liberation

Energy Meters and Reading

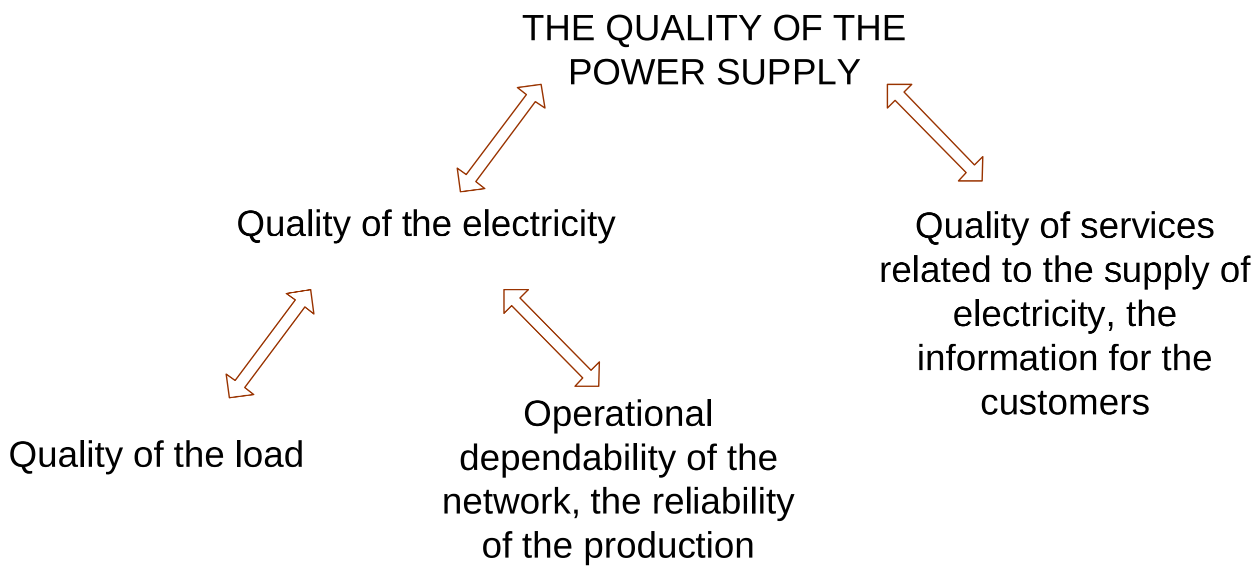
- Energy meters
  - Typically a property of the distribution utility
  - According to Electricity Market Act the customer or the vendor of electricity has also the right to buy and possess the equipment
- Meter reading events
  - 41 % are manual readings by distribution utilities
  - 24 % are remote readings
  - 24 % are customer manual readings, 10 % customer changes

READING EVENT	READ COUNT	PERCENTAGE	READING FREQUENCY
Manual reading	1 088 000	41,70 %	1
Remote reading	626 000	24,00 %	12
Customer reading	641 000	24,60 %	1
Customer change	255 000	9,80 %	1
Total	2 610 000		

Billing of household customers

- The billing of household customers has typically been based on customer type-specific load profiles.
- A load profile is a graph of the variation of the electrical load versus time.
- The Finnish customer-specific load profiles were formed by conducting extensive measurements in the 1980s and 1990s.
- According to the measurement results, the hourly power variation, spread of the average hourly capacity, and temperature dependence, have been identified for 40 different groups of electricity consumers. [LUT05]

Quality Control in Distribution of Electricity



- The quality of the power supply is determined by the quality of the electricity and the quality of the service
- The quality of the electricity can be divided further into the quality of the load and the operational dependability of the electrical network
- In Finland as in other European countries, the quality of the electricity is defined mainly from the quality of the load.
- The standards are based on the European standard EN 50160 and its national applications.

Compensation for Supply Interruptions

- The amendment (9/2003) that was made to the electricity market law in 2003, defines a percentual compensation of the yearly fee to be paid for customers in power failures
- The compensation applies for all power failures longer than 12 hours

Table 1: Compensation for supply interruptions [LUT05]

INTERRUPTION TIME	COMPENSATION
12…24 hours	10 %
24…72 hours	25 %
72…120 hours	50 %
over 120 hours	100 %

*Percentage of the yearly electricity bill, at most € 700 per client

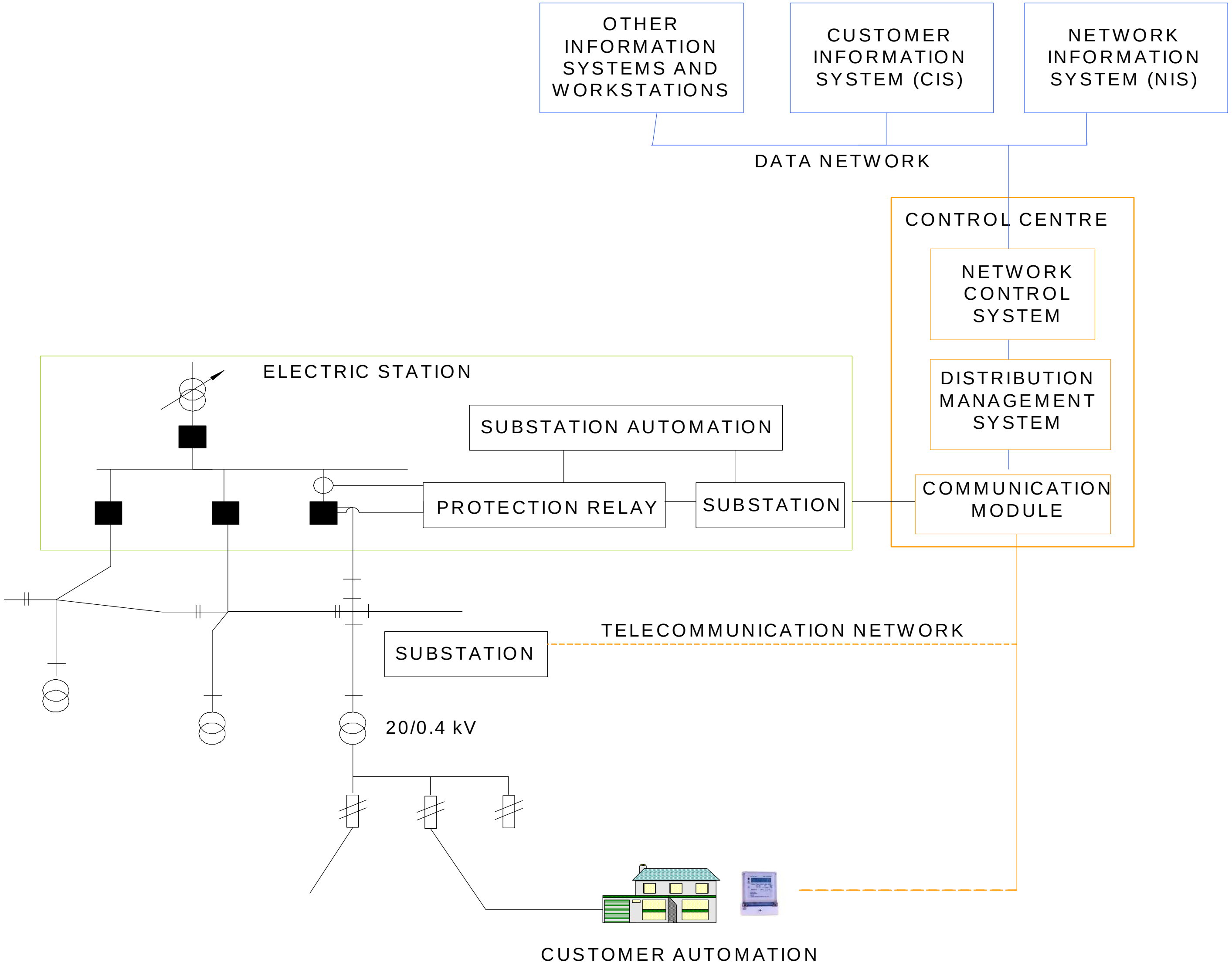
Energy Market Liberation

- Started in the Nordic Countries in 1991 from Norway.
- In Finland the sale and production of electricity was opened for competition in 1995
  - First, only bigger customers with powers of over 500 kW
  - In 1997, the power limit was removed and competition became possible for everyone
  - Smallest energy users into competition when load-profiles introduced in 1998 and need for the expensive meter removed
- Liberation regulated in the Energy Market Law

Electricity Distribution Automation

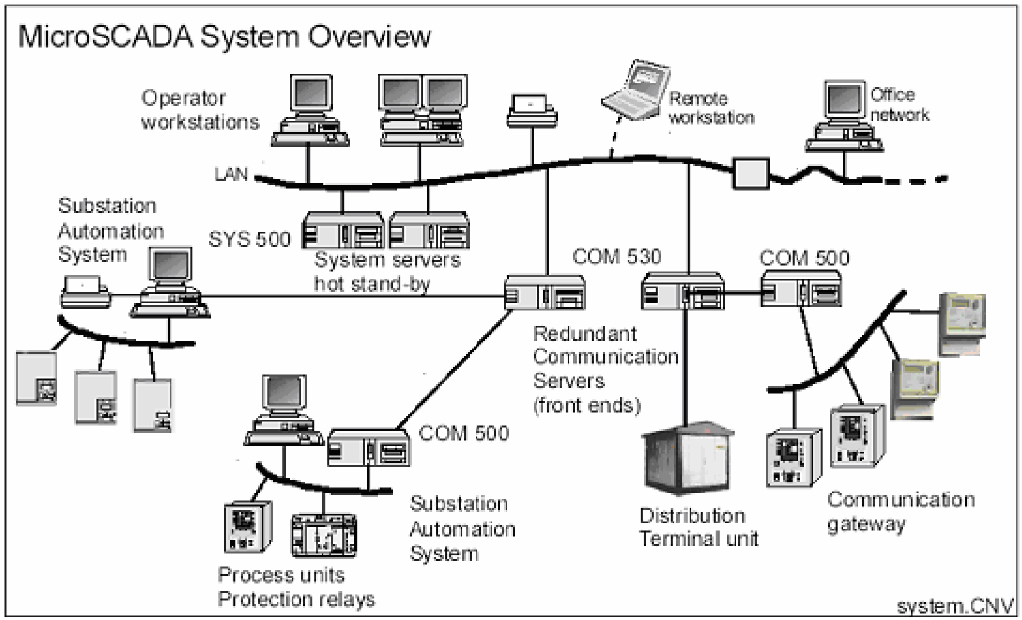
- Monitoring and control of the electrical distribution network
- Realized with information systems, such as
  - Network Control System (NCS)
  - Distribution Management System (DMS)
- Comprehends
  - Substation Automation
  - Network Automation and
  - Customer Automation

Electrical Network Automation



Network Control System

- Enables centralized remote control of the electrical network
- Network Control System includes a central information system that is located at the control center, IEDs located at the substations and in the distribution network, and communication connections between these units



Distribution Management System

- An operational planning system, which supports the distribution network operation via different supporting features
- Extends NCS capabilities by providing geographically based network views
- The purpose of the system is to minimize the operational costs of the electrical network at the same time taking into consideration the targeted process stability (supply level) and the limits set by technical restrictions

Possibilities in AMR for Distribution Mngmnt

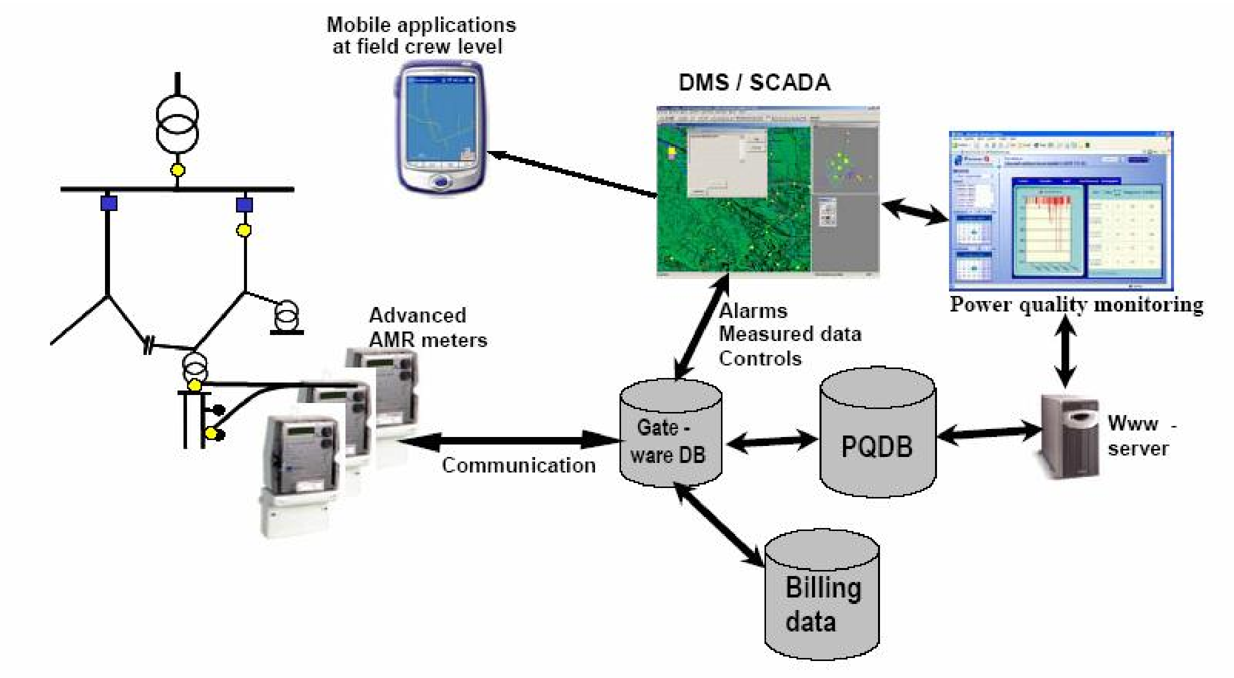
- Some AMR energy meters could generate useful data for the distribution network management
- The AMR system data could mainly be used in the management of the rural area distribution networks
- This data could be used in the Distribution Management System in application areas such as
  - Low voltage network fault management,
  - Outage and electricity quality management and
  - Network analyses

Low Voltage Network Fault Management(1/2)

- Low voltage network fault management has been based on customer notifications of electrical outages and malfunctioning devices.
- AMR meters units could provide data for the low voltage network management of events such as:
  - Blown fuse for the low voltage feeder,
  - Broken zero conductor to a customer meter,
  - Under/over voltage at the customer location and
  - LV network voltage unbalance due to broken MV network conductor

Low Voltage Network Fault Management(2/2)

- DMS could use the respective data in
  - Localization of a low voltage fault
  - Clarification of the fault magnitude,
  - Clarification of the cause of the fault and (origin) and
  - Faster commence of the LV fault restoration operations



Outage and Quality Management

- The following outage and quality data could be obtained from AMR meters:
  - Outage durations,
  - Voltage swells and sags,
  - Over voltage and
  - Harmonic waves

- This outage and quality data could be used in the distribution network management in:
  - Adjustment of the outage reports in the medium and low voltage networks
  - Customer information databases
  - Network analyses

Network Analyses

- Data obtained from AMR meters for the purpose of the network analyses could include, besides the quality and outage data:
  - Hourly metering data of the consumption of electricity and
  - Instantaneous power metering from the meter
- The application areas for this data could include
  - Generation of consumer specific load profiles and
  - Improved load estimation

Different Meter Reading Techniques

- Electronic Meter Reading (EMR)
  - Directly from the meter

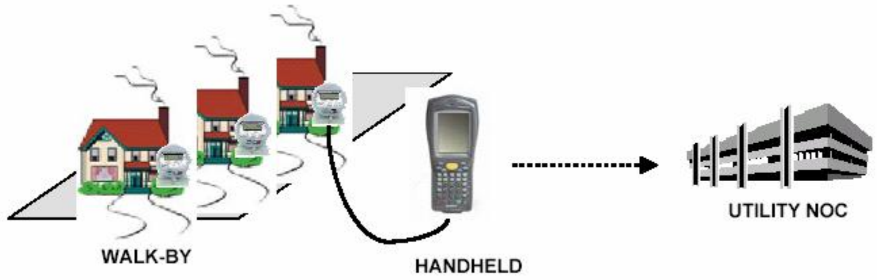
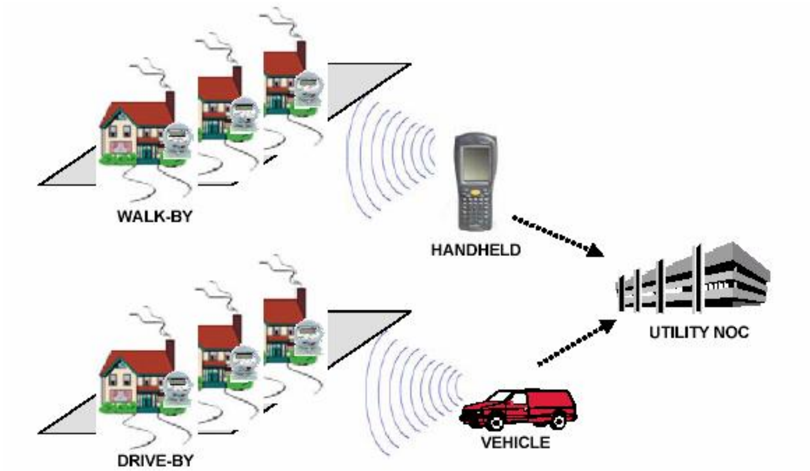


Figure 5-9 Electronic Meter Reading (EMR)



- Off-Site Meter Reading (OMR)
  - From a distance
  - Common in the Central Europe and the North America

- Automatic Meter Reading (AMR)
  - Via a telecommunication network
  - Common in Northern and Southern Europe

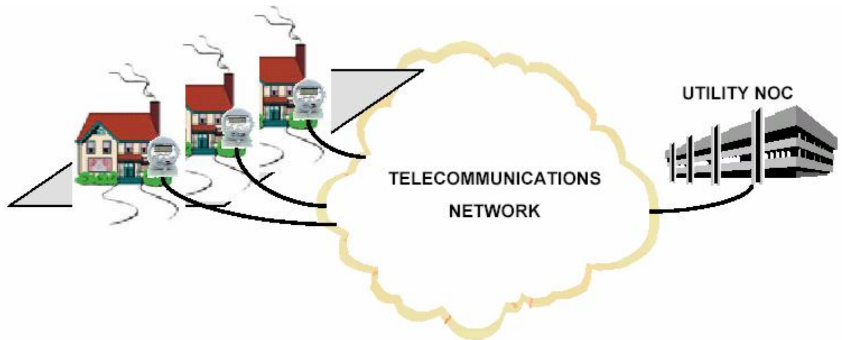


Figure 5-11 Automatic Meter Reading (AMR)

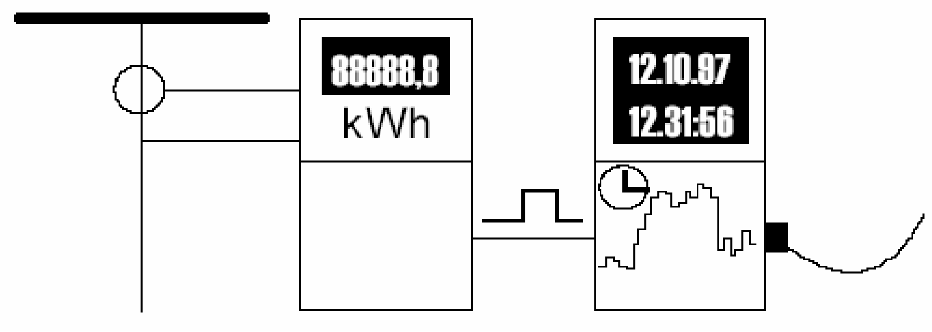
AMR System

Level	Components	Layer
LEVEL 4	CUSTOMER SERVICE; BILLING; METERING SITE MANAGEMENT; BALANCE SETTLEMENT; NETWORK OPERATIONS	ENERGY COMPANY PROCESSES
LEVEL 3	AMR INFORMATION SYSTEM FOR COLLECTING AND REFINING DATA	AMR SYSTEM
LEVEL 2	GSM/GPRS; LAN; PSTN; PLC	COMMUNICATION
LEVEL 1	HOUSEHOLD; COMMERCIAL AND INDUSTRIAL; GRID	CUSTOMERS

- Consists of basically four levels Meters, Communication, AMR information system and Energy Company Processes [Enermet]

AMR Meters

- AMR meter consists of
  - Energy meter
  - Collector unit and
  - Communication module



- On the right a modern electronic AMR meter developed for the Australian market. The front panel shows the present use of electricity, the current tariff (per hour) and the time for the next change in the tariff.

AMR Meter functions

- Measurement Frequency
  - Regularly
    - Once a month/day/hour
  - On a need basis
- Consumption Measurements
  - Household
    - Real power with different tariffs
  - Industry and real estate
    - Real and reactive power and maxim powers
    - Heat
    - Water [EnergyIndustry05]
- Customer and Vendor Offered Services
  - Controls
    - Tariffs
    - Load
    - Overload
- Remote connection and disconnection
- Other Information
  - Quality of electricity
    - Voltage level
    - Interruptions
    - Phase errors
  - Meter self diagnostic

AMR Meter Alarm functionality

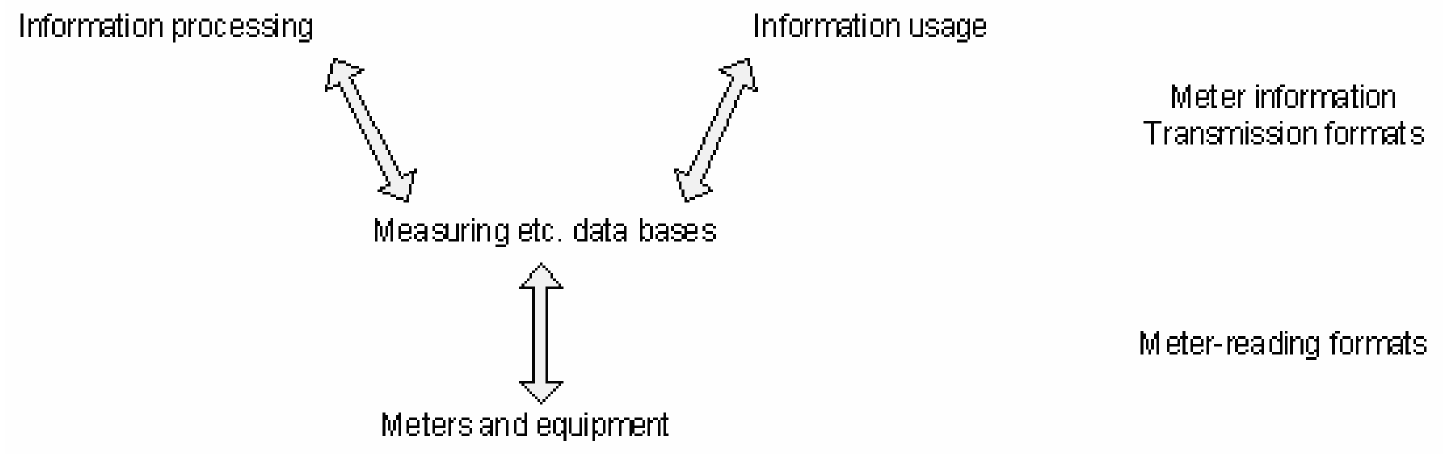
- Some existing meters include alarm functions
- The alarms can be read in conjunction with the energy data or they can be transmitted spontaneously
- The alarm functions are based on manufacturer-specific proprietary protocols but also is DLMS used
- Enermet has e.g. a separate Alarm management function, which enables spontaneous alarm messages
  - External inputs and internal statuses are controlled
  - Is not recommended for critical alarms due to restrictions in the meter and communication path

ABB

AMR Interfaces

- (1) Between the Meter and the AMR System
  - Meter Reading Standards (Protocols)

- (2) Between the AMR System and related Information Systems
  - Meter Information Transmission Formats



(1) Standards in meter data exchange

- IEC standards
  - IEC 62056-21 (formerly IEC 61107),
  - IEC 62056-53 (DLMS) / IEC 62056-62 (COSEM),
  - IEC 62056-31 (EURIDIS),
  - IEC 60870-5-101, IEC 60870-5-102
- ANSI standards
  - ANSI C12.18, ANSI C.19
- Other standards
  - MBUS,
  - LON,
  - TURTLE,
  - ELCOM and
  - PQDIF [Internet; OPEDAD41]

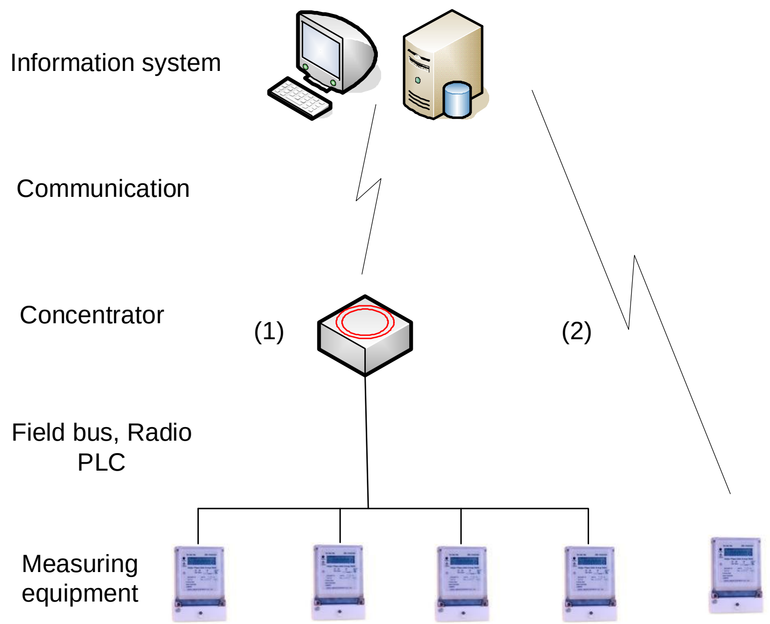
AMR Information System

- AMR information system database stores the remotely read measurement data.
- The database is called Metered Value Data Base (MVDB)
- The database can typically act as central data storage for several different AMR systems, or it can be the database of the only AMR system in use.
- The data can be processed and analyzed in the MVDB or it can be further rerouted to other information systems
- The exchange of data between the AMR information system and other information systems is typically conducted with standardized transmission formats or by exchanging files

Related Information Systems

- The information systems linked with the AMR system can include, among others
  - Customer Information Systems,
  - Billing Systems,
  - Network Control Systems,
  - Balance Settlement Systems,
  - Meter Management Systems and
  - Enterprise Resource Planning Systems (ERP, SAP, etc.) [Enermet06]
- Many of the respective information systems are situated at the distribution utility's premises and used in the daily operation of the distribution network business.

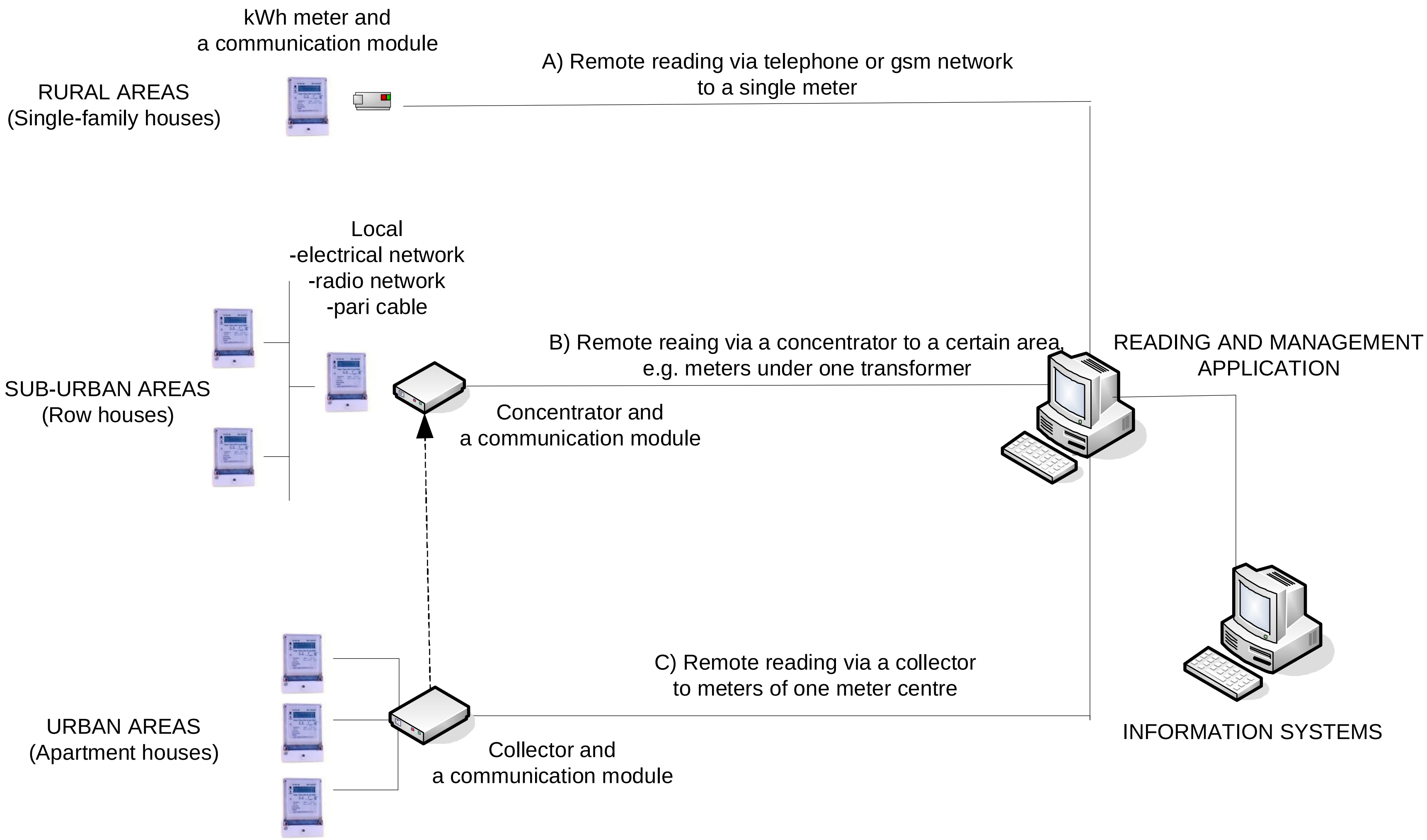
AMR Communication



- Divided by environments
  - (1) Urban Areas
  - (2) Sub-Urban Areas
  - (3) Rural Areas

- And divided in parts by communication technologies
  - (1)The part from the meter to the concentrator
  - (2) The part from the concentrator to the AMR System
  - (3) Direct communication from the meters to the IS

AMR Communication Environments



AMR Benefits for Distribution Utilities

IMPROVEMENTS IN:

- Billing
- Electricity losses
- Costs
- Balance settlement
- Tariff control
- Load shedding (control)
- Network planning
- Service control
- Load profile
- Change of the electricity seller
- Reporting
- Quality of electricity [EnergyIndustry05]

AMR Risks for Distribution Utilities

RISKS:

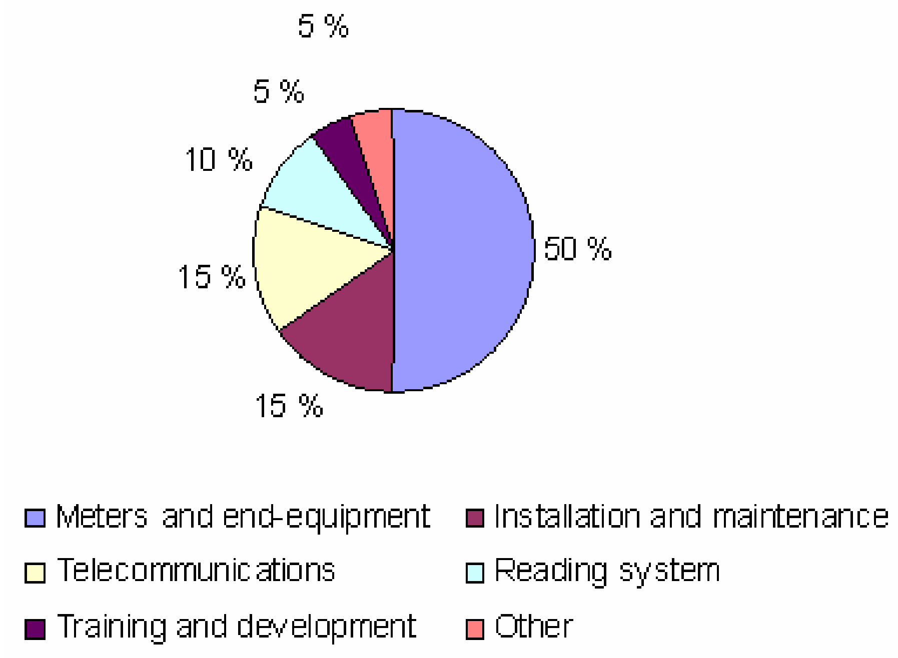
- Exceeded general costs
- Communication costs
- Supplier changes
- Unfinished products
- Short life cycle of technologies
- Wrongly selected solutions
- Malfunctions
- Disturbances, viruses, etc.
- Information system risks
- Personnel risks
- Changes in legislation
- Electricity Market Legislation, EU
- Data privacy
- Consumer Protection
- Vandalism
- Bad reputation in a case of a failure [EnergyIndustry05]

AMR Purchase

- AMR Purchase
  - By outsourcing the operation and the ownership of the system to an external solution provider,
  - By outsourcing only the operation of the system,
  - By purchasing and operating the system by itself
- The bigger distribution utilities tend to purchase the measurement data collection and management as a service from mobile operators.
- The smaller companies use smaller measurement service companies. [VTT06]
- AMR system implementation
  - Typically conducted in stages
  - First, a pilot project is executed
  - After the pilot, the rest of the AMR meters are implemented according to the experiences obtained from the pilot.

AMR Costs for Distribution Utilities

- Doctor of Technology Anssi Seppälä has estimated the cost division of the costs of an AMR project
  - Installations 50 %
  - Installation and maintenance 15 %
  - Telecommunications 15 %
  - Reading system 10 %
  - Training and development 5 %
  - Other 5 %



- Total cost of an AMR system for 15 years with 5 % interest rate
  - In average € 20 per metering point for urban areas
  - € 27 per metering point for rural areas [VTT]

Inspected Communication Technologies

- The communication can be either direct communication or a combination of the private and public methods

- The First Part / The Private technologies
  - Power Line Communications
  - UHF Radio

- The Second Part / The Public technologies
  - ADSL
  - WiMAX (New, no applications)
  - Flash-OFDM (New, no applications)
  - GPRS

- Direct Communication
  - GPRS, WiMAX (New, no apps), Flash-OFDM (New, no apps)

Event based Data

- An AMR meter could generate an alarm message, e.g. when certain object's (e.g. voltage level) predefined threshold is exceeded, or an abnormal event (e.g. outage) takes place in the electrical distribution network.
- The existing meter reading protocols support the event-generation to some degree
- Time-critical events are called alarms.
- An AMR meter could generate alarms from events such as:
  - Blown fuse for LV-Feeder,
  - Broken zero conductor to a customer meter,
  - Under voltage at the customer location,
  - Over voltage at the customer location and
  - Voltage unbalance in LV network due to broken MV network conductor

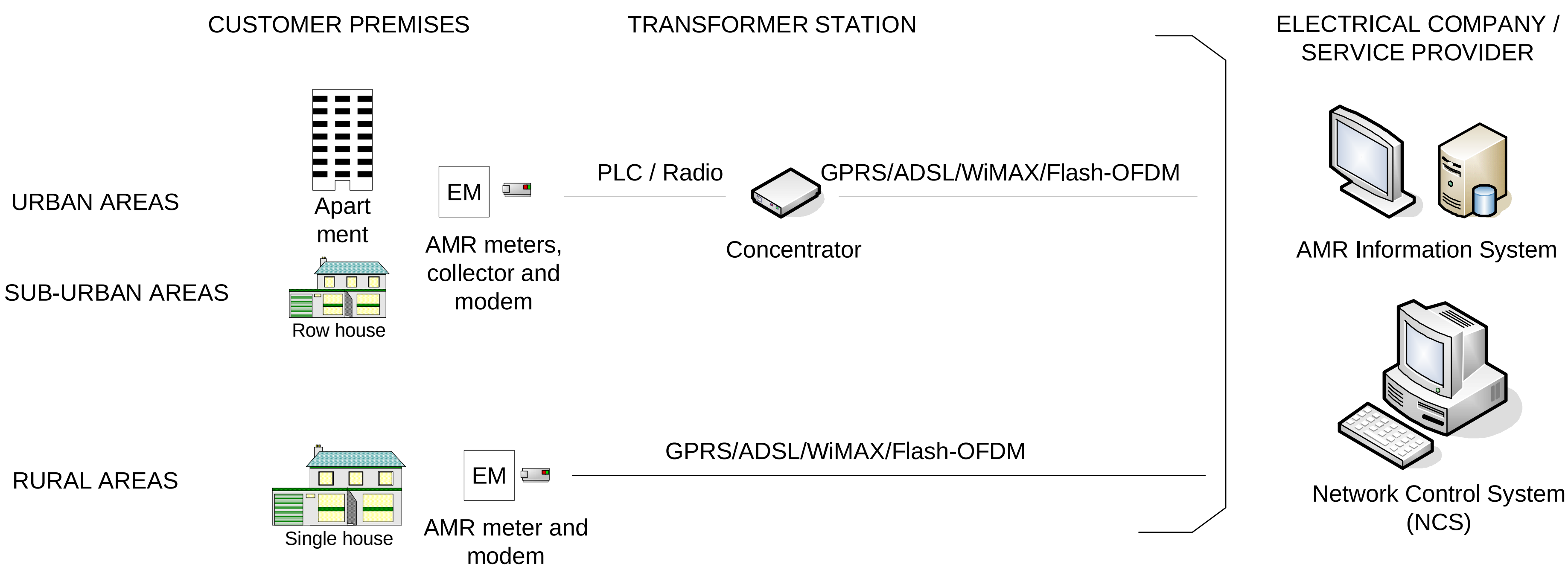
Technology parameters

- In some cases it is possible that many meters, e.g. in the same LV transforming circuit begin to transmit alarms at the same time.
- This sets some requirements for the communication network regarding the network congestion
- We have decided to take into consideration the following parameters:
  - Base station connection capacity (the amount of simultaneous connections),
  - Base station reach,
  - Technology data rate,
  - The reliability of the communication network

Cases

- Case I: A low voltage network outage. In the respective outage one LV feeder at a transformer station is without electricity (e.g. due to blown fuse for the LV feeder).
- Case II: An outage of one transformer station. This would mean that an entire transformer station and all the LV feeders would be without electricity.
- Case III: An outage of one MV feeder. Then, all the transformer stations under the respective feeder would be without electricity.
- Case IV: An outage of an entire substation. As a result, all the substation's MV feeders would be without electricity.

Technologies in the comparison



- Communication technologies' appliance in communication comparisons.
- We will leave PSTN and ADSL out of the comparisons, because the emphasis of our study is on wireless communication methods.

Technical Parameters

- Private vs. public technology initial data
- Bottleneck in connection capacities

PRIVATE COMMUNICATION TECHNOLOGIES	PLC	UHF RADIO
Data rate	3 000 bps	9 500 bps
Concentrator UPS	up to the DISCo	up to the DISCo
Concentrator reach	0,5 km	0,5 km
Concentrator capacity	1000 meters	1000 meters

PUBLIC COMMUNICATION TECHNOLOGIES	GPRS	WIMAX	FLASH-OFDM
Data rate per connection	54 000 bps	10 000 bps	300 000 bps
Base Station UPS*	3 h	2 h	1 h
Base station radius Urban Area	2 km	10 km	20 km
Base station radius Rural Area	20 km	10 km	20 km
Amount of sectors per base station	-	4	3
Amount of connections per sector	-	2200	125
Base station connection capacity Urban Area	30	8800	375
Base station connection capacity Rural Area	8	8800	375

CASE I, LV Feeder Outage

CHARACTERISTICS: LV Feeder Line	URBAN AREA	RURAL AREA
Length of the LV lines	0,3 km	0,8 km
Number of consumers per LV feeder	50	3
Number of consumers per concentrator	25	-

CASE I: OUTAGE OF ONE LV FEEDER	URBAN AREA	RURAL AREA
Number of consumers per LV line	50	3
Percentage of the meters that include alarms	25 %	100 %
Alarming meters (i.e. direct connections)	13	3
Connections if all meters behind a concentrator	2	-
LV feeder length	0,3 km	0,8 km

- The amount of consumers behind a LV Feeder
  - Urban Area 50 consumers
  - Rural Area 3 consumers
- In Urban Area 25 % of the meters include alarms, in the Rural area 100 %
- Thus, in the case of an outage, 13 respective 3 meters transmits alarms

CASE I, Results

CASE I: URBAN AREA	GPRS	WIMAX	FLASH-OFDM
Amount of base stations in use	1	1	1
Base Station Degree of utilization (no concentrators)	43 %	0 %	3 %
Base Station Degree of utilization (concentrators)	7 %	0 %	1 %

CASE I: RURAL AREA	GPRS	WIMAX	FLASH-OFDM
Aamount of base stations in use	1	1	1
Degree of utilization without concentrators	38 %	0 %	1 %

- About 40 % of the GPRS network capacity in the urban area is used and
- only 25 % of the meters transmitted alarms.
- If 100 % of the meters had alarm function, GPRS network would be 167% congested (1,67 times more pending connections than capacity).
- 38 % of the GPRS network would be occupied in the rural area
- WiMAX and Flash-OFDM would not be congested at all

CASE II, Transformer Station Outage

Table 1: Transformer station characteristics

CHARACTERISTICS: Transformer Station	URBAN AREA	RURAL AREA
Number of LV feeders per transformer	6	3
Number of consumers per TS	300	9

Table 2: Transformer station outage characteristics

CASE II: TRANSFORMER STATION OUTAGE	URBAN AREA	RURAL AREA
Number of consumers per TS	300	9
Percentage of the meters which include alarms	25 %	100 %
Alarming meters (i.e. direct connections)	75	9
Connections if all meters behind a concentrator	12	-
LV feeder length	0,3 km	0,8 km
Side length of the Area (if were regtangle)	0,6 km	1,6 km
Geographical Area covered by the Transformer station	0,28 km2	2,01 km2

- 300 respectively 9 consumers behind a tranformer station in the urban and rural environments
- In an outage situation 75 respectively 9 meters would start to transmit alarm messages
- If concentrator is used in the urban area, only 12 connections needed

CASE II, Results

Table 1: Case II results: Public technologies

CASE II: URBAN AREA	GPRS	WIMAX	FLASH-OFDM
Aamount of base stations in use	1	1	1
Base Station Degree of utilization (no concentrators)	250 %	1 %	20 %
Base Station Degree of utilization (concentrators)	40 %	0 %	3 %

CASE II: RURAL AREA	GPRS	WIMAX	FLASH-OFDM
Aamount of base stations in use	1	1	1
Degree of utilization without concentrators	113 %	0 %	2 %

- In both the urban and rural environment the amount of direct alarm connections would grow so high that GPRS network would not be able to process all the connections at a time.
- However, the delay would be minimal
- Also, the Flash-OFDM network load increases to about 20 percent in the urban area whereas the WiMAX network would use only about 1 percent of its base station capacity.

CASE III, MV Feeder Outage

Table 1: MV feeder line characteristics

CHARACTERISTICS: MV Feeder Line	URBAN AREA	RURAL AREA
Length of the MV lines	4 km	40 km
Number of TS per MV feeder	12	30
Number of consumers per MV feeder	3600	270

Table 2: MV feeder outage characteristics

CASE III: OUTAGE OF ONE MV FEEDER	URBAN AREA	RURAL AREA
Number of consumers per MV feeder	3600	270
Percentage of the meters with alarms	25 %	100 %
Alarming meters (i.e. direct connections)	900	270
Connections if all meters behind a concentrator	144	-
Length of MV feeder line	4 km	40 km

- An urban MV feeder line is about 4 km and the rural MV feeder line about 40 km long in the example network structure.
- A MV feeder contains 12 respective 30 transformer stations (TS) and the number of consumers per MV feeder rises up to 3600 respectively 270.
- In the respective MV feeder outage 900 respectively 270 meters would transmit alarms. The concentrators would decrease the urban area number down to 144

CASE III, Results

Table 1: Case III results: Public technologies

CASE III: URBAN AREA	GPRS	WIMAX	FLASH-OFDM
Amount of base stations in use	2	1	1
Base Station Degree of utilization (no concentrators)	1500 %	10 %	240 %
Base Station Degree of utilization (concentrators)	240 %	2 %	38 %

CASE III: RURAL AREA	GPRS	WIMAX	FLASH-OFDM
Aamount of base stations in use	2	3	2
Base Station Degree of utilization (no concentrators)	1688 %	1 %	36 %

- GPRS network base stations are congested. In both areas the load would be over 1500 %.
- This means that there would be 15 times more pending alarm connections than connection capacity in the network.
- WiMAX and Flash-OFDM would do better than GPRS due to greater capacity.
- However, the Flash-OFDM base station in the urban area would also slightly exceed its capacity.
- As can be seen from Table 22, in the loads would be spread on several base stations

CASE IV, Substation Outage

Table 1: Substation Characteristics

CHARACTERISTICS: Substation	URBAN AREA	RURAL AREA
Number of MV feeder lines per substation	30	10
Number of consumers per substation	108000	2700

Table 1: Substation outage characteristics

CASE IV: SUBSTATION OUTAGE (ALL MV FEEDERS)	URBAN AREA	RURAL AREA
Number of consumers per substation	108000	2700
Percentage of the meters with alarms	25 %	100 %
Alarming meters (i.e. direct connections)	27000	2700
Connections if all meters behind a concentrator	4320	-
Length of MV feeder line plus LV feeder line	4 km	41 km
Side length of the Area (if were regtangle)	8,6 km	81,6 km
Geographical Area covered by the substation	58,06 km2	5226,97 km2

- If an entire substation would be without electricity, approximately 108000 respectively 2700 households would be affected.
- These households would be in the 30 respectively 10 MV feeders starting from the substation.
- In the urban area the length of MV electric wires exceeds up to 4000 meters and in the rural areas even up to 40 000 meters.
- The amount of meters with alarm functionality would sum up to 27000 respectively 2700 meters.
- The geographical area covered by the substation in the urban environment would be approximately 58 km2 and in the rural area 5230 km2.

CASE IV, Results

Table 1: Case IV results: Private technologies

CASE IV: URBAN AREA	GPRS	WIMAX	FLASH-OFDM
Aamount of base stations in use	10	1	1
Base Station Degree of utilization (no concentrators)	9000 %	307 %	7200 %
Base Station Degree of utilization (concentrators)	1440 %	49 %	1152 %

CASE IV: RURAL AREA	GPRS	WIMAX	FLASH-OFDM
Aamount of base stations in use	9	34	9
Base Station Degree of utilization (no concentrators)	3750 %	1 %	80 %

- In the urban area, the connection load would be spread at least between 10 GPRS base stations.
- Also the WiMAX and Flash-OFDM networks would be severely congested but would be using the same base station.
- In the rural area, the load is spread between 9 GPRS or Flash-OFDM base stations and 34 WiMAX base stations.
- WiMAX and Flash-OFDM networks would be able to handle all the incoming alarm connections immediately, while GPRS network would be congested and the transmission would take more time.

Case Interpretation

- GPRS network's capacity to transmit several alarm connections at the same time can be limited.
- The network can in average handle the alarms coming from an outage of one LV feeder when 25 percent of the meters include the alarm function and form a direct connection between the meter and the AMR information system.
- If the percentage of the alarming meters was increased, or if the outage covered e.g. the whole transformer station or more, GPRS network's capacity to transmit simultaneous connections at the same time would insufficient.
- The alarms would then be delayed for a certain period of time and the messages would get through after several connection establishment efforts.
- In this respect, Flash-OFDM and especially WiMAX clearly beat GPRS network.

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Example Data Transmission

Table 1: Example data of alarm transmission

ALARM TRANSMISSION DATA	Seconds
GPRS average connection capacity per base station	30
GPRS connection establishment time	5,0 s
Alarm transmission	1,0 s
Successfull alarm transmission in average	6,0 s
Connection busy- detection time	2,5 s
Retransmission after	10,0 s

- We have used the following data estimating the duration or an alarm transfer
  - Connection establishment time 5 s
  - Alarm transmission 1 s
  - Connection busy-detection time 2,5 s
  - Retransmission time 10 s

GPRS network congestion

Table 1: Alarm transmission times in GPRS network with congestion

ALARM TRANSMISSION TIMES						
Alarming connections	10	20	40	80	160	360
GPRS base station congestion	33 %	67 %	133 %	267 %	533 %	1200 %
Alarms transmitted in	6,0 s	6,0 s	18,5 s	31,0 s	68,5 s	143,5 s

- When the load of the base station is fewer than 100% of the capacity, the alarms are transmitted in about 6 seconds (5 seconds connection establishment and 1 second alarm data transmission).
- If the network is congested, some meters have to wait a while and then try to retransmit the data.
- We have used 10-second delay between retransmission attempts. This way the transmission time for 360 direct alarm connections is calculated to be 144 seconds.
- The WiMAX and Flash-OFDM networks have a better theoretical capacity for transmission of several connections at the same time
- However, the respective networks do not have total coverage in Finland, nor any products for the AMR systems.

Proposals for Decreasing the Congestion

- Only the necessary meters alarm (depending on the type of the alarm)
- Meters are polled for alarms by the concentrator or the central system (a lot of data traffic in the network)
- Transmission of alarms is staggered in certain time limits
- Concentrator includes intelligence and filters the alarms (could increase delay)
- QoS mechanisms are applied to the alarms messages (and networks)

Direct vs. Two stage solution - Initial data

Table 1: Investment data

INVESTMENT INFORMATION	
Interest rate	5,00 %
Investment duration (years)	15
Investment duration (months)	180

Table 2: Electrical network information for the cost comparison

ENVIRONMENT AND METER INFORMATION	
Environment (Urban/Rural)	Urban
The total amount of invested meters	4
Max meter count per LV feeder	50
Max meter count per TS station	300
Max meter count per ES	108000
The amount of required feeder lines	1
The amount of required TS	1
The amount of required substations	1
Distances	
between the meters and TS	0,3 km
between the meters and ES	4,3 km

- We have tried to calculate the cost difference for the two communication solutions: direct communication and two-stage communication.
- We have used GPRS in the direct communication and the PLC and GPRS in the two-stage solution.
- We have discounted all costs for a 15-year investment period to the present with 5 percent discount rate.
- We have used the Urban Environment data and compared the costs of the communication solutions by changing the amount of meters.

Direct vs. Two stage solution - Excel sheet

Table 1: Communication costs for direct communication (incl. connections)

DIRECT COMMUNICATION			
Communication technology	GPRS		
COSTS			
CAPEX	**à**	**total**	**pv**
Meters with communication modules	250 €	1000 €	1000 €
Total		1000 €	1000 €
OPEX	**à**	**total**	**pv**
Monthly communication costs	3 €	2160 €	1517 €
Total		2160 €	1 517,46 €
TOTAL COMMUNICATION COSTS		3160 €	**2 517,46 €**
TOTAL COMMUNICATION COSTS PER METER			**629,37 €**
TOTAL COMMUNICATION COSTS PER METER PER YEAR			**41,96 €**

Table 2: Communication costs for two-stage communication (incl. connections)

TWO-STAGE COMMUNICATION			
Communication technoloy 1	PLC	units	
Concentrators needed	YES	1	
Number of connections	1	units	
Repeaters needed	NO	0	
Communication technology 2	GPRS		
COSTS			
CAPEX	**à**	**total**	**pv**
Meters with communication modules	230 €	920 €	920 €
Concentrators with communication modules	1000 €	1000 €	1000 €
Repeaters	300 €	0 €	0 €
Total		1920 €	1920 €
OPEX	**à**	**total**	**pv**
Monthly communication costs for technology 1	0 €	0 €	0 €
Monthly communication costs for technology 2	3 €	540 €	379 €
Total		540 €	379 €
TOTAL COMMUNICATION COSTS		2460 €	**2 299,37 €**
TOTAL COMMUNICATION COSTS PER METER			**574,84 €**
TOTAL COMMUNICATION COSTS PER METER PER YEAR			**38,32276214**

Results and Conclusions (1/3)

- Automatic Meter Reading can enable the use of new the low voltage network data in the distribution network management. This data includes real-time alarm data, quality data and accurate consumption data.
- Three main application areas for the respective data in the distribution network management could be divided into the low voltage network fault management, outage and electricity quality management, and network analyses.
- Possible benefits from this new data include efficiency in the clearance of the fault cause and magnitude, improved outage reporting, improved awareness of the power distribution situation and improved planning of the distribution network, among others.

Results and Conclusions (2/3)

- IEC 62056-53 / IEC 62056-62 (DLMS/COSEM) is one of the few meter reading standards that is compatible with several suppliers' meters and AMR systems. It supports event-based communication to some detail. Proprietary standards and systems also tend to support event-based data, but they function only inside the respective supplier's systems.
- The alarm functionality of the AMR systems is developing as we speak but the connection with the electrical network control systems is still minor. The meters will be configured according to the meter situation in the network to alarm of only certain types of events. With the customized configuration unnecessary alarm messages are avoided and the telecommunication network congestion can be reduced.

Results and Conclusions (3/3)

- GPRS seems to be the main AMR communication technology in the Nordic Countries, whereas PLC is the typical technology in South Europe. In the case of a large-scale outage in the distribution network, simultaneous alarm messages can possibly get the GPRS network temporarily congested quite easily. In the future, Flash-OFDM and WiMAX could be considered as alternatives for the GPRS communication. They have better congestion tolerance and data rates but at the moment have no solutions for AMR and the prices are high. AMR PLC systems enable also spontaneous alarm messages, but the PLC in general does not seem to be very reliable communication technology. The time that is needed for the PLC systems (1-stage or 2-stage) to transmit various alarm messages at the same time was not clarified and needs further studies.
- According to our calculations, the direct GPRS communication is a cost effective alternative in transforming circuits that have 4 or less customers. When the number of customers increases, the two-stage alternative should become more cost-effective. However, when excluding the connection costs the direct communication is more economical up to 50 meters LV circuits and from thereon the solution costs are equal.

Assesment of Results

- Due to the nature of the input parameters (estimations) the results obtained from the technical and economical calculations can be considered as trendsetting. However, the calculation sheet that acted as the basis for the comparisons can be used in the adjustment of the results when more accurate input data will be available.
- Even though being just trendsetting, the results show the potentiality of the new communication technologies (WiMAX and Flash-OFDM) and the vulnerability of GPRS network to handle several critical connections at the same time.

Exploitation of Results

- This Thesis acts as a basis for the mapping of the current situation regarding the Automatic Meter Reading and its connection to the electrical network control. Based on the material and results obtained from this thesis, ABB Substation Automation and Distribution Automation can decide more profoundly the future guidelines regarding the integration between the advanced metering systems and control systems of the electrical distribution network. It is very probable, that the AMR systems will be integrated to the electrical network control systems in the near future.

Future Studies

- There remains a lot to study in respect to the Automatic Meter Reading. E.g., the economical benefits of the new services enabled by AMR for distribution utilities require more investigation.
- At the moment at least two bigger AMR projects are beginning in Europe. The AMR Nordic Forum and ESMA (European Smart Metering Alliance) projects try to gather experiences of intelligent remote readable meters and further clarify the requirements for them. [VTT06]

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