

SMART METER

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Outline

- ▶ **Smart meter basics**
- ▶ **Smart meter technology**
- ▶ **Smart meter issues**

Smart Meter Basics

Electrical Power

► Electrical power

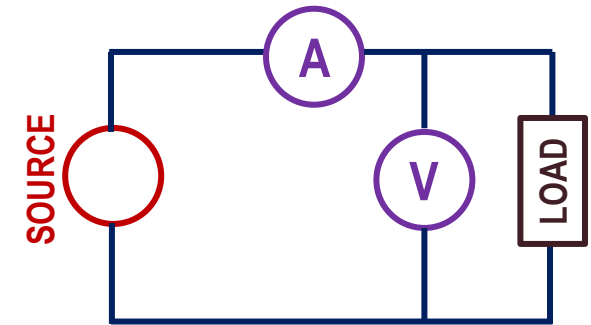
- Active/real power
- Reactive power

► Active/real power

- $P = V \times I \times \cos\phi = (\text{volt}) \times (\text{amp}) \times (\text{power factor})$
- $V = \text{voltage}$, $I = \text{current}$, $\phi = \text{angle between } V \text{ and } I$, $\cos\phi = \text{power factor}$
- **W (watt), kW: unit of active/real power**

► Reactive power

- $P = V \times I \times \sin\phi = (\text{volt}) \times (\text{amp}) \times (\text{reactive factor})$
- $\sin\phi = \text{reactive factor}$
- **VAR: unit of reactive power**



A: Current Meter, V: Volt Meter

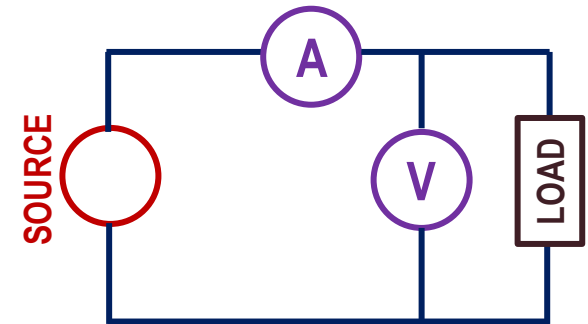
Electrical Energy

► Electrical energy

- Total energy consumed by a load over a period of time
- $E = P \times t$
- t = time
- Wh (watt-hour), kWh: unit of electrical energy
- 1 kWh = 3,600,000 joules

► Cost of electrical energy

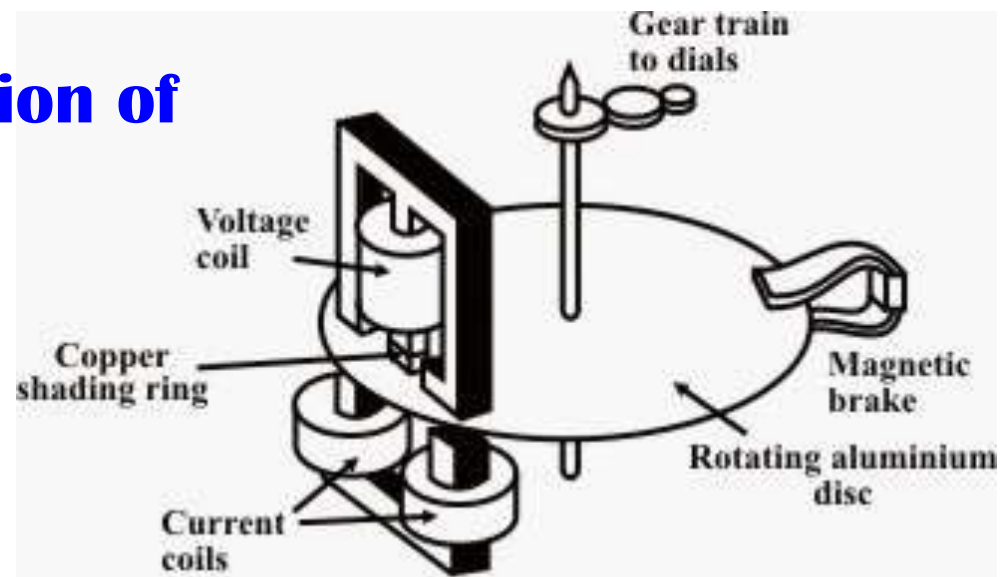
- $C = E \times \$$
- \$ = unit cost of electrical energy



A: Current Meter, V: Volt Meter

Energy Meter

- ▶ **Measures the consumption of electrical energy**
- ▶ **Types**
 - **Analog meter**
 - **Digital meter**
- ▶ **Analog Meter**
 - **Based on electromechanical induction principle**
 - **Aluminum disc rotated by magnetic induction of two coils**
 - **Voltage/pressure coil**
 - **Current coil**



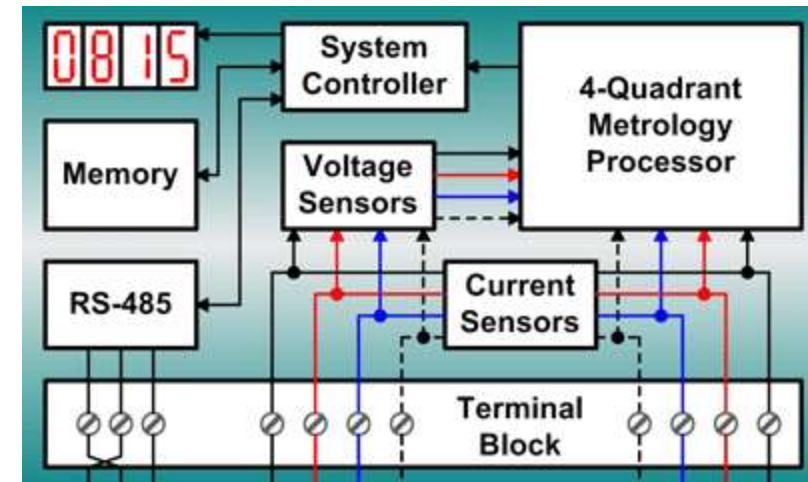
Watt-hour meter.



Energy Meter

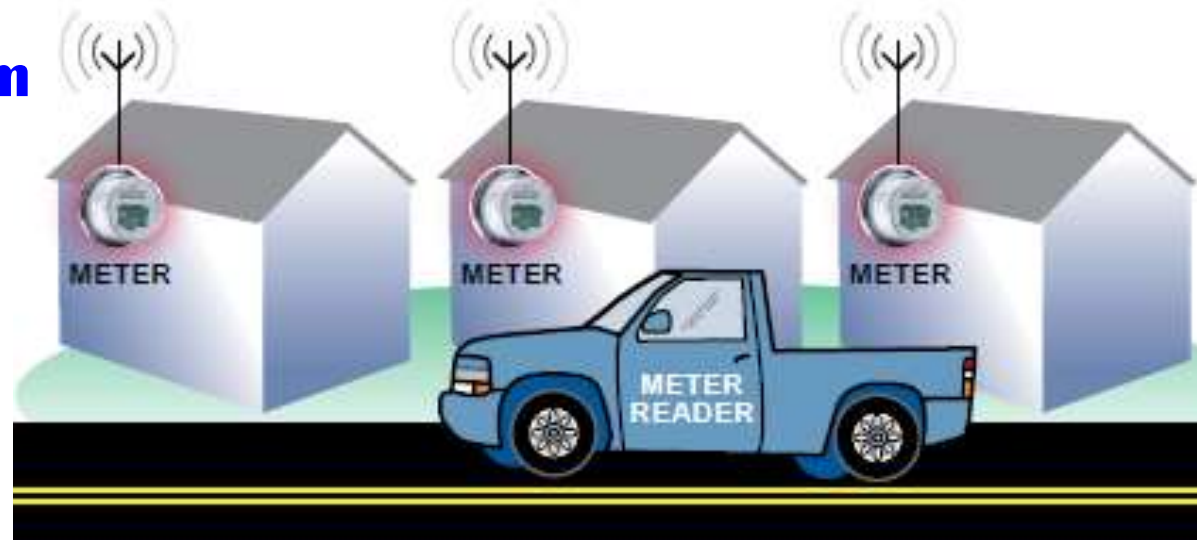
► Digital meter

- Voltage and current are sampled and quantified
- Digital signal processor calculates power
- Integration over time yields energy
- Energy data displayed on LCD
- Can also measure power factor and reactive factor
- Not influenced by external magnets or meter orientation
- Highly reliable



Automatic Meter Reading

- ▶ **Automatic meter reading (AMR)**
 - **Electronic meter – reliable and accurate measurement**
 - **Communication technology – transmit data**
- ▶ **Remote meter reading**
 - **Walk-by**
 - **Drive-by**
 - **Networked system**



Automatic Meter Reading

- ▶ **Automatic meter reading (AMR)**
 - **Automatically collect consumption, diagnostic and status data**
 - **Transfer data to central database for billing, troubleshooting and analysis**
- ▶ **AMR components**
 - **Advanced metering infrastructure (AMI)**
 - **Remote meter reading**
 - **Management of energy and expenses**
 - **Communication network**
 - **Radio frequency (RF)**
 - **Power line carrier (PLC)**

Smart Meter

- ▶ **Electronic device capable of recording energy consumption and communicating with the utility for monitoring and billing**
- ▶ **Green technology**
 - **Allows utilities to moderate peak load and avoid fossil-fuel-based short-term energy**



Smart Meter

► Components

- A meter capable of recording electricity consumed or generated by a customer
- A computer for logging and processing data and controlling interconnected devices
- A modem to communicate with nearby meters of network infrastructure



Smart Meter Features

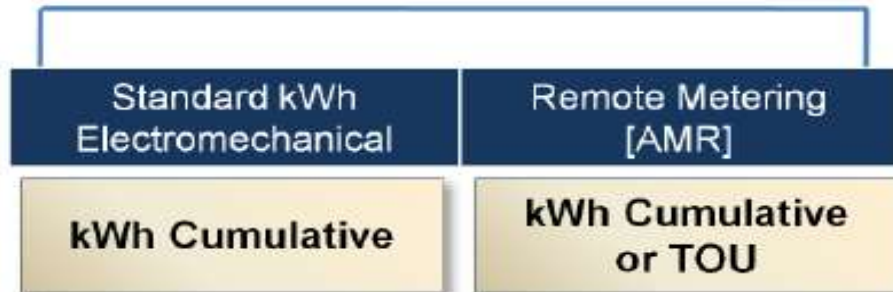
- ▶ **Efficient method for obtaining usage data**
 - **Eliminates physical meter reading**
 - **Manpower**
 - **Physical facilities**
- ▶ **Accurate meter reading**
 - **Highly efficient and accurate digital processor**
 - **Also up-to-the-minute information on consumption patterns**
- ▶ **Improved billing**
 - **Allows different pricing applications, like time-of-use**
 - **Transparency of “cost to read” metering**

Smart Meter Features

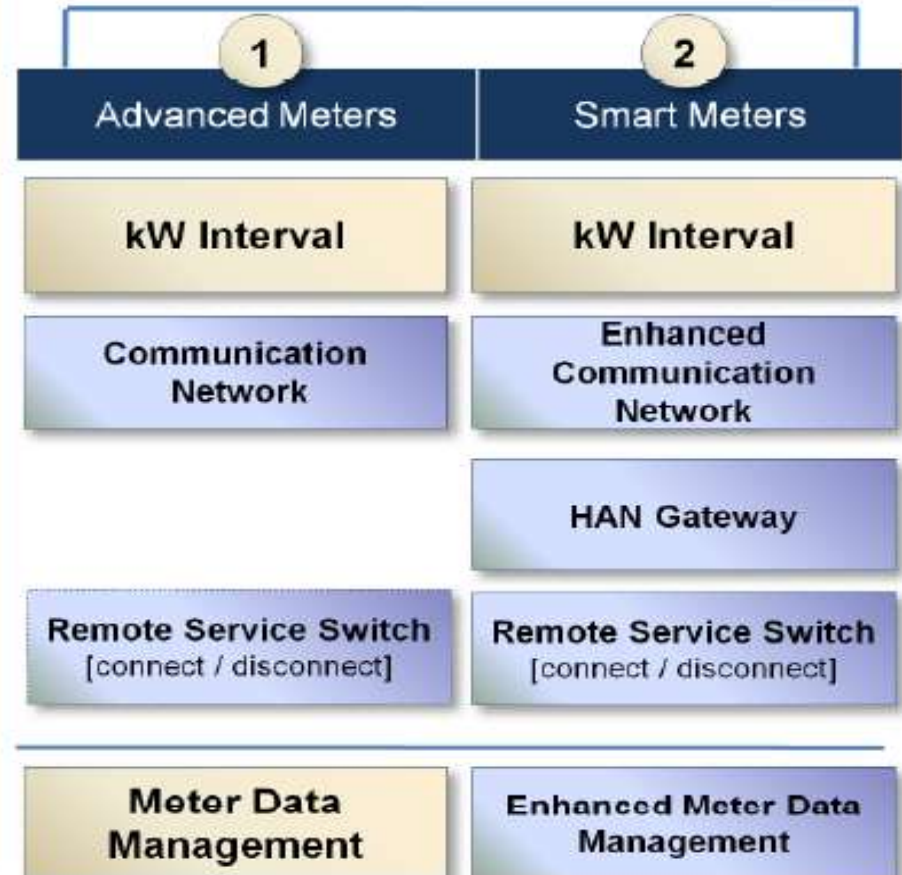
- ▶ **Efficient energy management**
 - Energy management through profile data graphs
 - Utility can manage/allocate supply in cases of shortages
 - Accurate profile classes and measurement classes
 - Improved procurement power through more accurate data – “de-risking” price
- ▶ **Financial advantages**
 - Less financial burden correcting mistakes
 - Less accrued expenditure
- ▶ **Improved security**
 - Improved security and tamper detection for equipment

Electric Meters

Traditional Meters



Advanced Metering Infrastructure



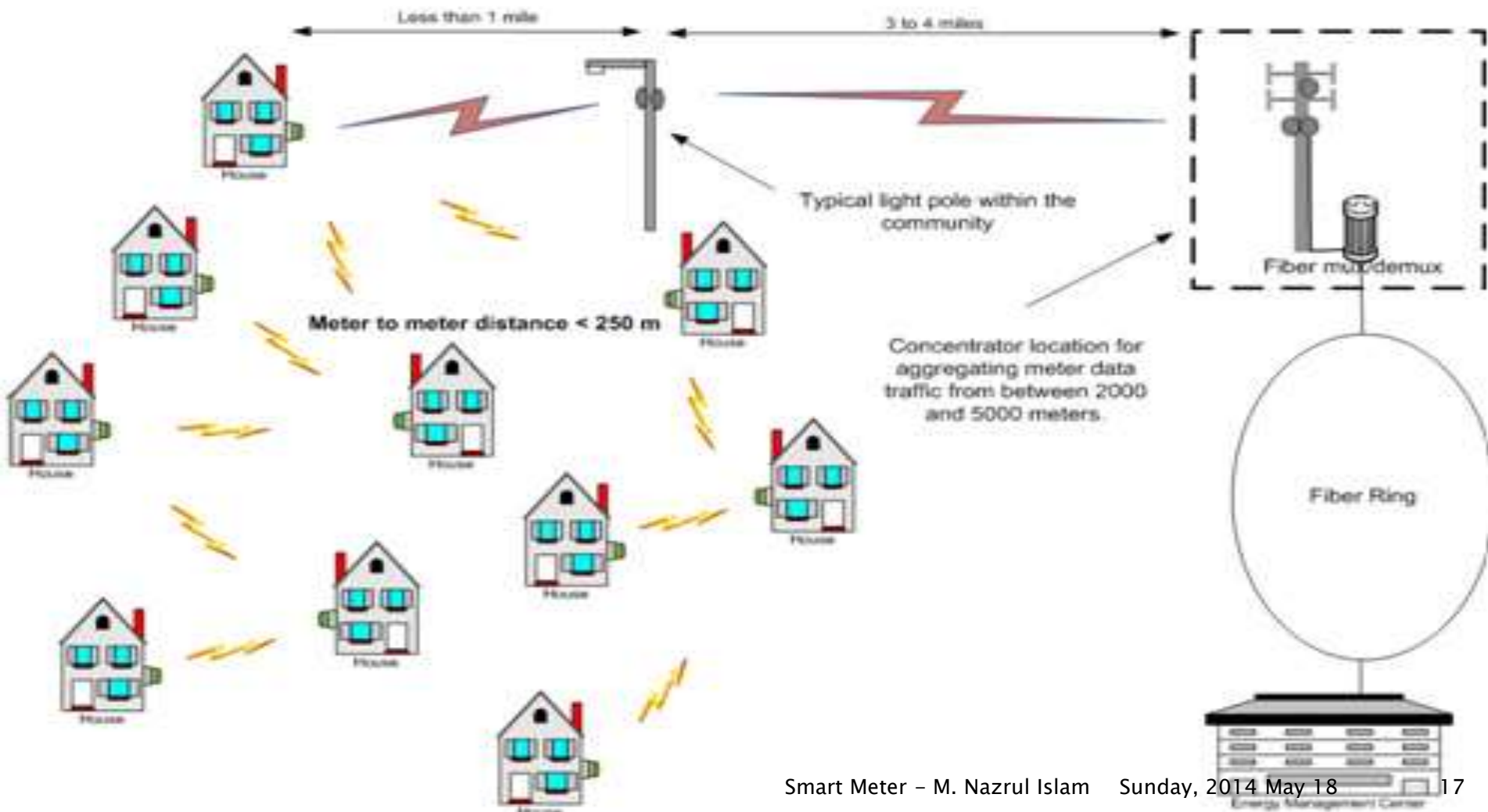
Smart Meter Technology

Technology

- ▶ **Smart meter technologies**
 - **Communication**
 - **Protocols**
 - **Data management**

Communication Technology

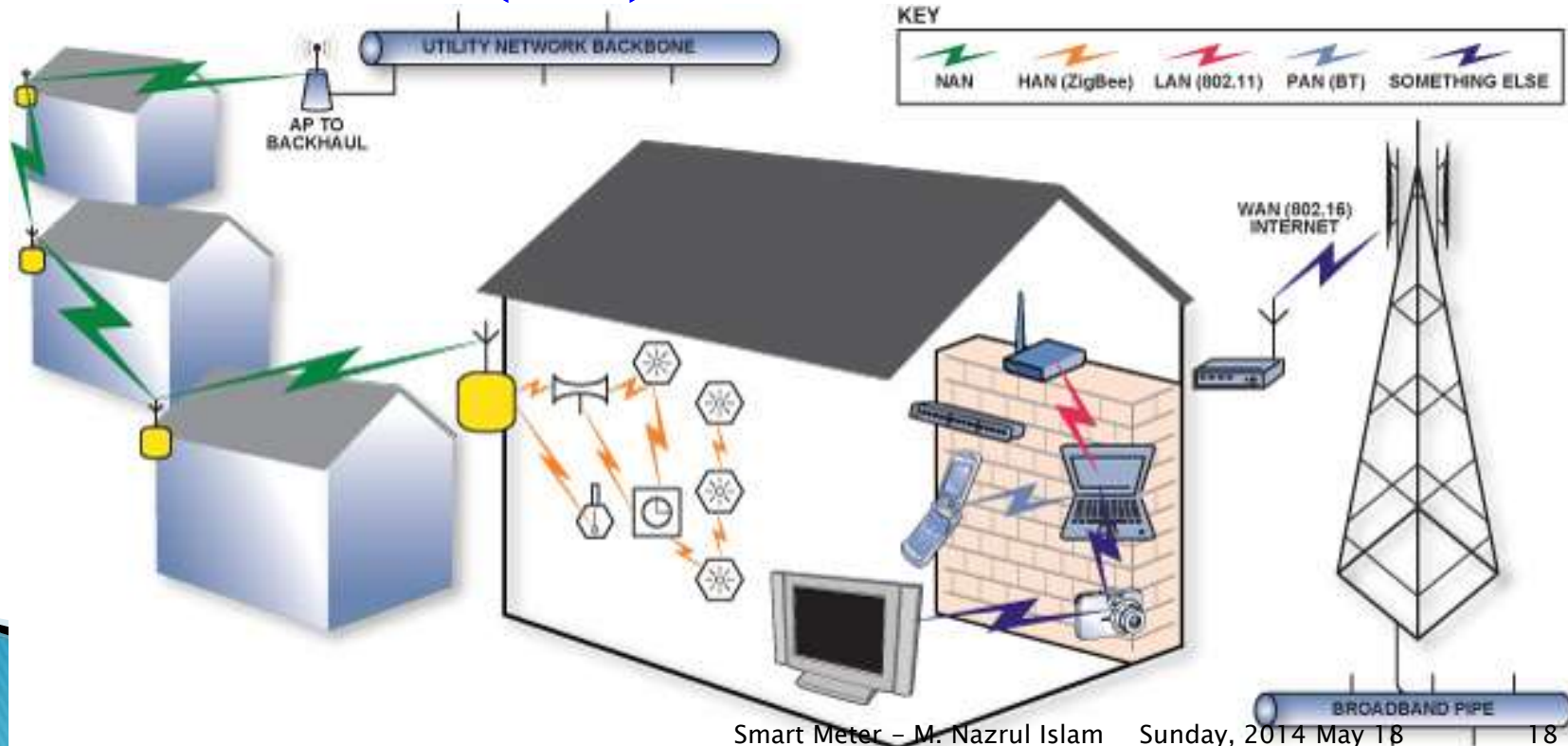
TYPICAL RESIDENTIAL NETWORK ARCHITECTURE



Communication Technology

► Communication networks

- Home area network (HAN)
- Neighborhood area network (NAN)
- Wide area network (WAN)



Communication Technology

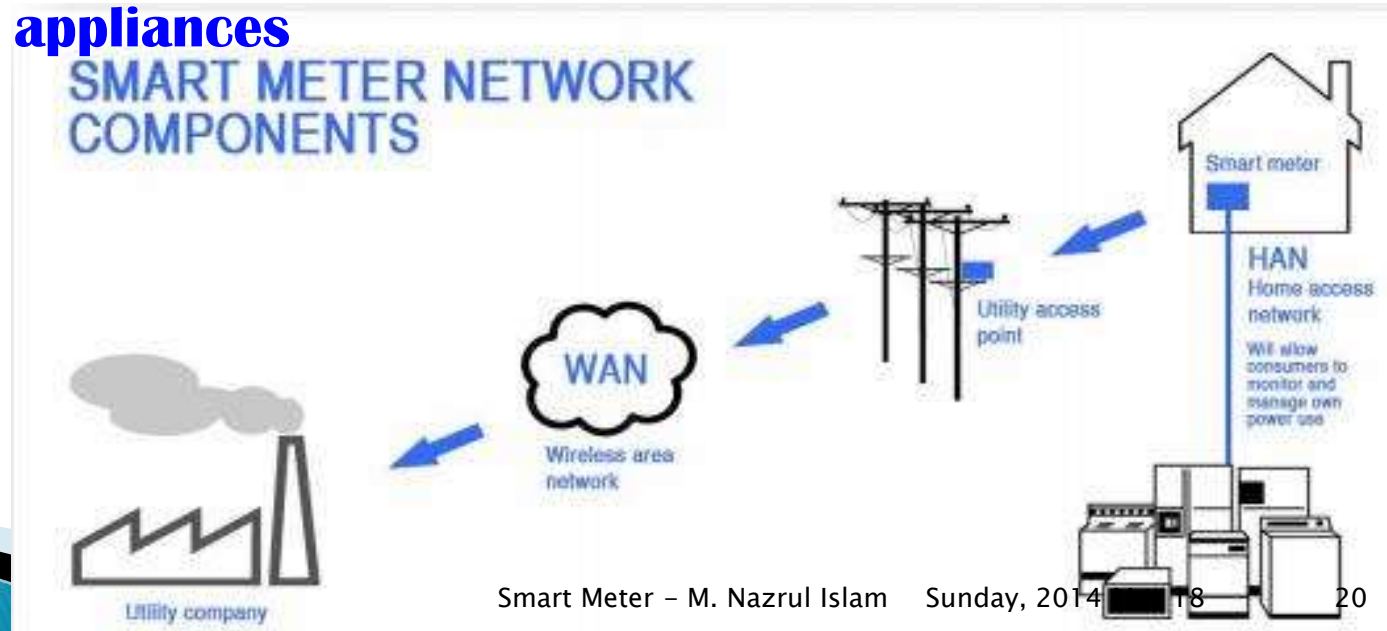
► Communication networks

- **Home area network (HAN)**
 - **Equipment throughout the house are in wireless network with a central coordination and data collection node within the residence**
 - **Enables a household to receive data describing its electrical usage behavior and optimize energy usage efficiency**
- **Neighborhood area network (NAN)**
 - **Information from end users are collected through a NAN**
 - **Low-power transmitters and local receivers or data collectors**
- **Wide area network (WAN)**
 - **Data transmitted to service provider over a WAN for analysis and management**

Communication Technology

► Home area network (HAN)

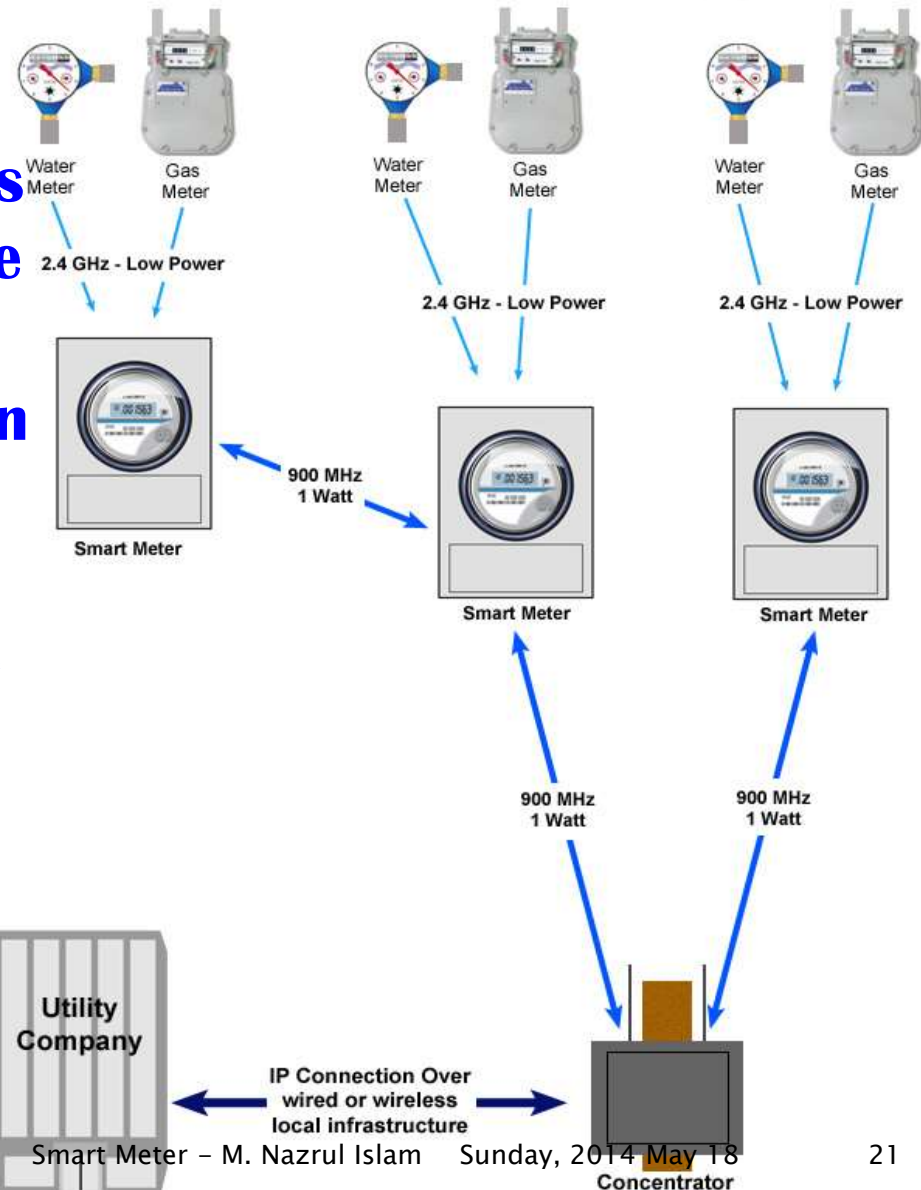
- Utilities extend to customer's homes to actively manage transmission load
- Utilities may communicate to appliances at home via smart meter
 - Turn up thermostat
 - Switch off appliances



Communication Technology

► RF technology

- Influenced by other wireless signals in and around home
- High sensitivity is required for long signal transmission
- Communication protocol must comply with radio emission regulations in the country
- Typical frequencies: 900 MHz, 2.4 GHz, 5.8 GHz



Smart Meter Issues

Issues/Concerns

- ▶ **Loss of privacy**
 - Usage data may reveal information about user activities
- ▶ **Loss of control**
 - Utility can control amount allocated to users
 - Utility can remotely shut off users
- ▶ **Security risks**
 - Increased security risks from network or remote access
 - Greater potential for monitoring by other/unauthorized third parties
- ▶ **Reduced reliability**
 - More complicated meters, more potential for interference by third parties

Issues/Concerns

- ▶ **Employment issue**
 - Meter readers losing jobs
- ▶ **Health concern**
 - Health implications of exposure to RF signals within and around a residence
- ▶ **Data management**
 - Meter reading cycle increases significantly
 - Data volume increases
- ▶ **Regulatory compliance**
 - Appropriate governance and compliance arrangements are critical to satisfying regulatory requirements and relevant industry codes

Security Requirements

- ▶ **Smart meter is a gateway to the household**
 - **Access to customer information**
 - **Ability to control signals**
- ▶ **Security threats**
 - **Unauthorized access**
 - **Causing malfunction of equipment or system**
 - **Masquerading**
 - **Repudiation**

Security Requirements

► Security requirements

◦ Confidentiality

- Only sender and receiver shares information
- Information is not disclosed to any unauthorized party

◦ Integrity

- Message is authentic
- Has not been altered during transmission

◦ Availability

- Data/service is available to legitimate users

◦ Nonrepudiation

- Accountability of sender and receiver
- Cannot deny they were part of information exchange

Security Requirements

► Smart meter security

◦ Confidentiality

- Energy usage data represent user characteristics, activities
- Physical threats may arise through disclosure of user data
- Marketing firms may gather user data to sell their products

◦ Integrity

- Commands from utility be unaltered
- Hacker may send disconnect commands

◦ Availability

- Smart meter data be available to utility for monitoring and billing
- Software glitches, component failure, physical damage or tampering may cause unavailability

◦ Nonrepudiation

- Repudiation may cause shattering of energy billing

Security Requirements

▶ Smart meter

- Confidentiality of data accrued by smart meter
- Integrity of commands sent from utility
- Availability of smart meter

▶ Customer gateway

- Interface into customers home and connected to important equipment
- Load control and pricing signals command at the gateway have financial impact on user

▶ Communication network

- Communication must be secure and reliable

Security Requirements

► Concentrator

- Processes data of a neighborhood
- Can be rendered as a single point of failure
- Needs be cost-effective but robust

► Headend

- Control center for billing, curtailment, control
- Data can be modified, dropped, replaced
- Invalid data and control commands may be issued reset meters, connect/disconnect meters and distributed generation devices, change pricing signals and initiate demand response
- Information gathered for future operations may repudiated
- Strong IT security techniques and policies must be adopted

Health Concerns

- ▶ **Research reveals the following**
 - **RF exposures, at sufficiently high levels, may increase the body temperature**
 - **No other specific biological effects have been confirmed or generally accepted**
- ▶ **Exposure guidelines and standards**
 - **Specify limits for the general public as well as for groups including workers**
 - **Requires training to be aware of their environments**
- ▶ **Exposure standards**
 - **Institute of Electrical and Electronics Engineers (IEEE, 2005)**
 - **International Commission on Non-Ionizing Radiation Protection (ICNIRP, 1998)**
 - **Federal Communications Commission (FCC, 1997)**

Health Concerns

- ▶ **Maximum permissible exposure (MPE) to RF**
 - Plane wave equivalent power density expressed in units of milliwatts per square centimeter (mW/cm²)
- ▶ **Absorption of RF energy is a function of frequency**
- ▶ **Specific Absorption Rate (SAR)**
 - Time rate of energy deposited per mass of tissue
 - Usually stated in watts per kilogram of tissue (W/kg)
- ▶ **Benchmark for behavioral disruption**
 - Approximately 4 W/kg

Subject	Exposure Limit (W/kg)	Safety Margin
General public	0.4	10 times less
Workers	0.08	50 times less

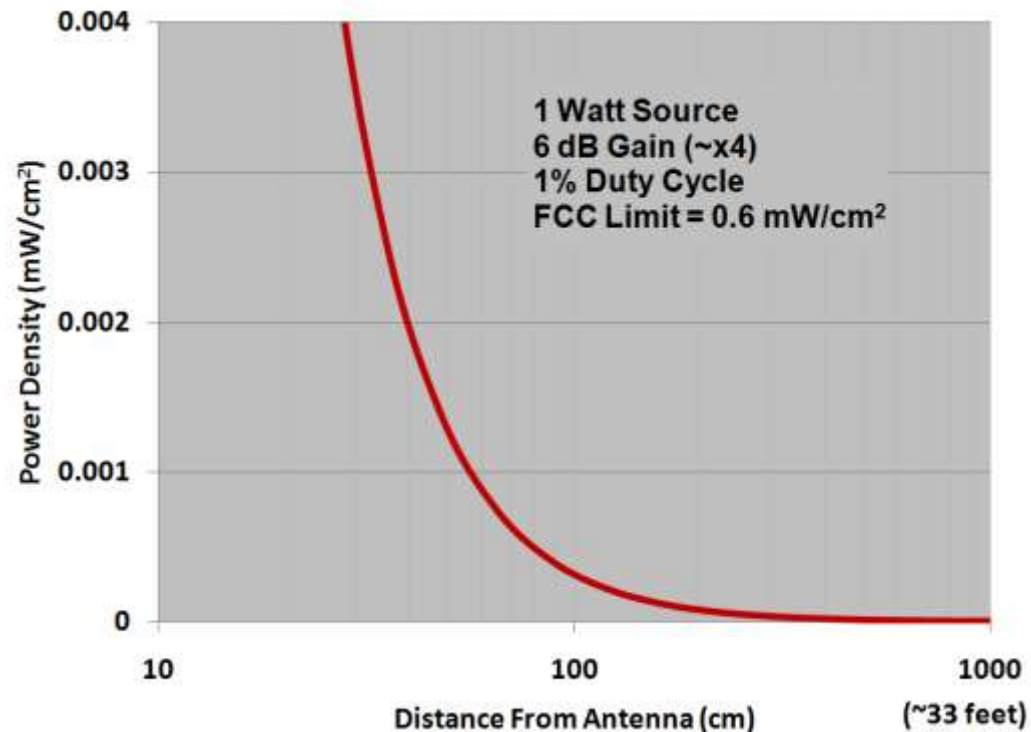
Health Concerns

▶ RF exposures

- Cell phones
- Computer wireless network
- Broadcast (radio/TV) signals

▶ Smart meter RF

- Transmits only a few seconds in a minute
- Operates at low power
- RF field decays significantly with distance away from antenna
- Average radiation is far below safety standards



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THANKS SO MUCH

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