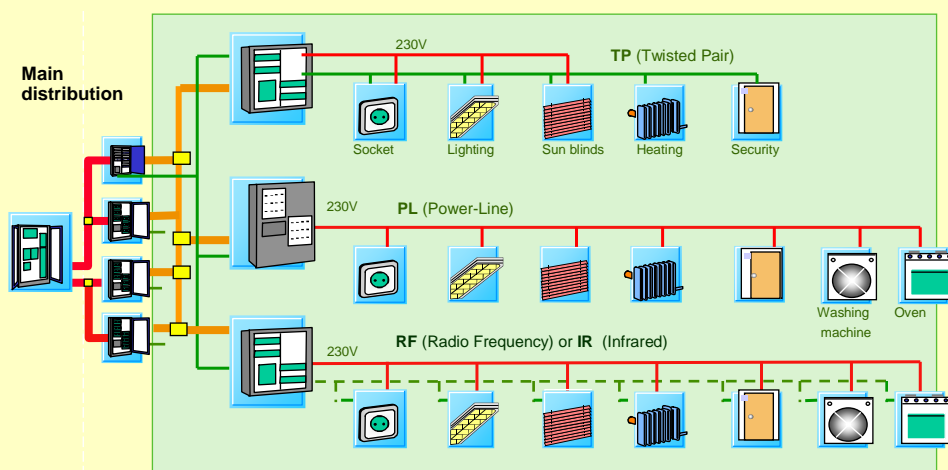# Home & Building Automation

parte 2

Corso di reti
per l'automazione industriale
Prof. Orazio Mirabella

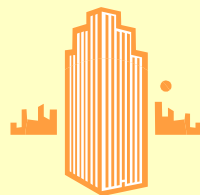# Technologies for Home automation

Communication media

- Twisted pair
- Coax
- Fiber optics
- infrared
- Power line
- Wireless

PLC -- Power Line Communication

- 60%+ U.S. homes have Internet access
- 10% broadband
  - Inaccessible and costly
- PLC = No new wires:
  - Emerging Technology
  - Use of Power grid for communication
 - Extensive infrastructure
    - "Every" building

PLC

- Features
- Home-Plug 1.0 PLC networking protocol
- Other services (in the house)
  - In-home entertainment
  - Internet home appliances
- BPL -- Broadband Power Line (outside house)
  - A "last-mile" technology
  - Wireless Internet

PLC -- Problems

1. Need high frequencies: current lines designed @ 50-60 Hz to 400 Hz
2. Contaminated -- noise, unreliable
3. Legal restrictions on frequency bands limit data rates
4. Power Loss
   - Directly proportional to square of current
   - Proportional to distance
   - High, medium, & low voltage lines & customer premise lines

PLC -- Previous Use

- Due to past low data rate communication needs, utility companies used PLC to maintain power grid
- New technologies allow high data-rate communication over low-tension lines
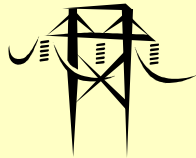
Regulatory Constraints

- Regulatory agencies
  - Federal Communications Commission (FCC)
  - European Committees for Electrotechnical Standardization (CENELEC)
- North America
  - 0 to 500 kHz and part of 2 to 30 MHz unlicensed spectrum are used for PLC
- General -- Regulate
  - Band allocation
  - Radiation emission
  - Power transmission on band

European Regulations

Frequencies / Use

1. 3-9 kHz: energy providers; customers premises
2. 9-95 kHz (A-band): energy providers & concession holders
3. 95-125 kHz (B-band): energy provider's customers
4. 125-140 kHz (C-band): energy provider's customers
5. 140-148.5 kHz (D-band): energy provider's customers
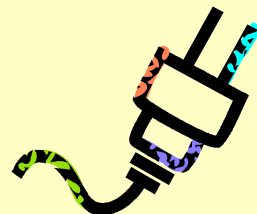   – B & D-band no access protocol defined

European Regulations

6. 2-30 MHz
   – Home plug 1.0 uses
   – Unlicensed by FCC
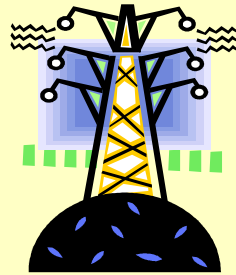   – Europe: efforts to develop a standard for electromagnetic compatibility with PLC

General: Regulate
   – Band allocation

Power Line Characteristics

- Not designed for high frequencies
- Power line "hostile" to signal propagation

Attenuation in PLC

- *The decrease in the value of something
- Decrease in amplitude of an electrical signal
- Opposite of amplification
- Dependant upon <u>Impedance</u>

Impedance in PLC

- *The opposition a circuit presents to an electrical circuit (in ohms)
- Maximum signal received <u>only</u> when impedance of all components (transmitter, power line, receiver) match
- Power line systems vary significantly
- Also varies with signal frequencies, time, load pattern
- Mismatches are destructive
- Ethernet & other dedicated lines have known impedance

Noise in PLC

- Major source: Electrical Appliance
  - e.g. run vacuum cleaner when TV on
  - those @ 60 Hz (N.A.) & 50 Hz (Eur.)
- Also radio signals from broadcast, commercial, military, CB, amateur stations
- 3 categories of appliance noise
  - Impulsive: on/off switches
  - Periodic impulsive: dimmers
  - Continuous impulsive: AC motors (vacuum, shavers) -- most severe)

PLC Electromagnetic Compatibility

- Power lines are <u>leaky</u>: radiate high-frequency electromagnetic signals
- Interferes with nearby wireless devices
- Need filters to prevent leakage
- 802.11b wireless network protocol (WiFi)

Modulation

- Process of varying a carrier signal to use the signal to convey information
- Analog vs. digital
- Amplitude, phase, frequency
- Why? To allow different components compatible
- Modem: modulate -- demodulate

PLC Modulation Scheme: Necessary Properties

1. Ability to overcome nonlinear channel characteristics
    -   PLC is very nonlinear
    -   Requires expensive, complex equalization to obtain more than 10 Mbps
    -   Should overcome without highly involved channel equalization

2. Ability to cope with multipath spread
    -   Impedance mismatch causes echo signal, delaying signal by ~1ms
    -   Must handle delays

PLC Modulation Scheme: Necessary Properties

3. Ability to adjust dynamically
    -   PLC changes with load
    -   Must track without large overhead or complexity

4. Ability to mask certain frequencies
    -   PLC uses unlicensed frequency band but regulations limit radiation in some sub & adjacent bands
    -   Masking would help marketability of PLC

Orthogonal Frequency Division Modulation Scheme - OFDM

- OFDM -- Collection of transmission techniques
- OFDM meets all desirable properties
- Used in European digital audio broadcast (DAB)
- Also in some variants of 802.11x -- wireless protocols
- Used in Home Plug 1.0

PLC Protocols
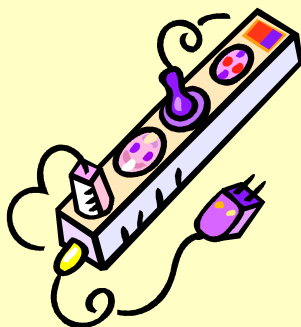
- Several for low-bandwidth digital services
- Products for home automation & home network are based on these
- Differ in modulation, frequency, channel access

X-10 Protocol

- Oldest, uses ASK modulation
- Originally unidirectional -- controller to devices
- Some bidirectional products
- Typically, signals over PL to receivers controlling lights & appliances
- Poor bandwidth utilization
  - 60 bps on 60 Hz line
- Poor reliability in noisy environments
- Limited application

KNX protocol

- KNX is an international standard communication protocol for home automation.
- KNX is based on standard protocols for the EIB (European Installation Bus), BatiBus, and the EHS (European Home System).
- KNX supports several communication media, including twisted pair, power line, radio-frequency, and Ethernet.

KNX®

CE Bus Protocol

- Peer-to-peer communication
- Avoids collisions via CSMA/CRCD protocol (carrier sense multiple access/collision resolution & collision detection)
- Physical layer: spread spectrum technology patented by Intellon Corp.
- Sweeps thru frequencies rather than hopping
  - From 100 to 400 kHz
  - Sweep called chirp -- used for synchronization, collision resolution, data transmission
- Data rate ~10kb/s
- Frequency used limits use in North America

Lon Works Protocol

- Peer-to-peer communication
- Developed by Echelon Corp.
- Uses CSMA
- Narrow band spread spectrum modulation
  - 125 to 140 kHz
- Patented noise cancellation technique
  - Preserves data in presence of noise
- Can be used in N. America and Europe
  - Due to narrow band

Home Plug 1.0 Protocol

- Achieves Ethernet class network on-site using existing electrical wiring
- Has been introduced in American market
- Mitigates unpredictable noise
- Splits bandwidth into many small sub channels
  - Masks noisy ones & others
  - Maintain 76 for use in U.S. market
- Data rate: 1 to 14 Mbps
  - Nodes estimate each 5 sec. & adapt to optimal data rate
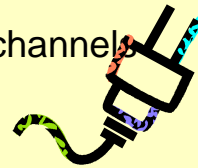
PLC Security

- PLC is shared channel (like WiFi)
- Robust security is serious issue
- Encryption necessary: security vs. complexity
  - Rivest: 128 bit key
  - Home Plug: DES - 56 bit key
- Intrusion & interference from adjacent subnets
  - e.g. Apartments - contention, degradation
  - Decoupling filters - isolate circuits at meter
  - Can also "separate" power line with router

PLC -- Summary

- **Tremendous potential**
  - Existing infrastructure
  - Much research -- many companies
  - Relatively low cost
- **Obstacles**
  - Compatibility, security, reliability
  - Bandwidth
  - Regulatory issues
- **Two related "problems"**
  - Inside house vs. Outside the house