EE 5223 - Lecture 42 Friday April 21, 2023

Ongoing List of Topics:

- URL: https://pages.mtu.edu/~bamork/EE5223/
- Term Project - Due Monday 1:00pm ET. Improvement extension: 9am Thurs.
  - Final presentations - Zoom (Monday 3:00 - 5:00pm) Attendance taken.
- Digital filters used in relays, Fourier filter example.
- PMUs, Merging Units. Publishing and subscribing to data.
- SCADA protocols, Event Recorders, transducers
- Real-time Communications for protection & control
  - PLC, leased lines, optic, VHF, UHF, MW, wireless, satellite, BPL
- Smart Grid
  - PMUs, synchrophasors
  - Station bus vs. Process bus
  - IEDs
  - Merging Unit
- Wrapup
  - Term Project Report
  - One last “assessment”
  - Term Project Presentations

Team Presentations volunteered so far:

1. **Team 7:** “High Impedance Faults caused by trees”
2. Team __
3. Team __
4. Team __
5. Team __
6. Team __

Some pointers on final report:

Executive Summary - one page, three paragraphs

- Orientatation/refresh on what the problem was and why project carried out
- Overview of what was done
- Results, conclusions and recommendations

- Statement of Contributions (one paragraph for each team member)
- “Hard skill” contributions: engineering analysis, design, programing, simulation, lab testing, etc.
- “Soft skill” contributions: literature search, technical writing/drawing/documentation, presentations, etc.
- Name and signature below each paragraph. Whole team must agree.

Final Grade:

20% - midterm (free points since no midterm was scheduled)
45% - Homeworks
5% - participation, discussion, meeting milestones
30% - term project and ppt presentation
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100%

EE 5223 - Term Project Evaluation

1) Selection of topic, applicability to this course, timely/relevant _____

2) Organization, grammar, spelling, format, figures, eqns. _____

3) Technical level befitting EE5000-level course, scope vs. group size. _____

4) Literature search, background theory & concepts _____

5) Development and implementation of your idea _____

6) Results _____

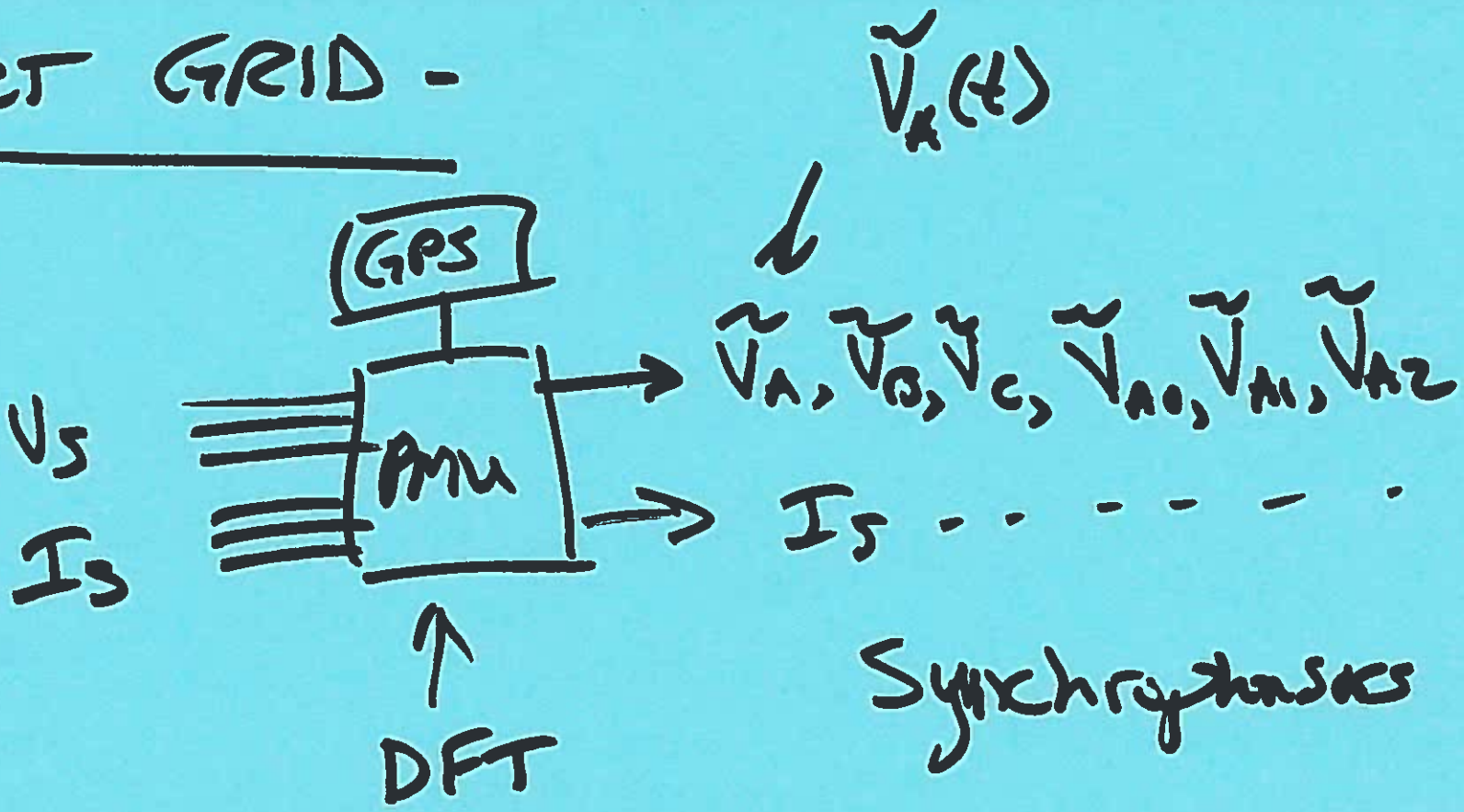
7) Complete coverage, conclusions, recommendations _____

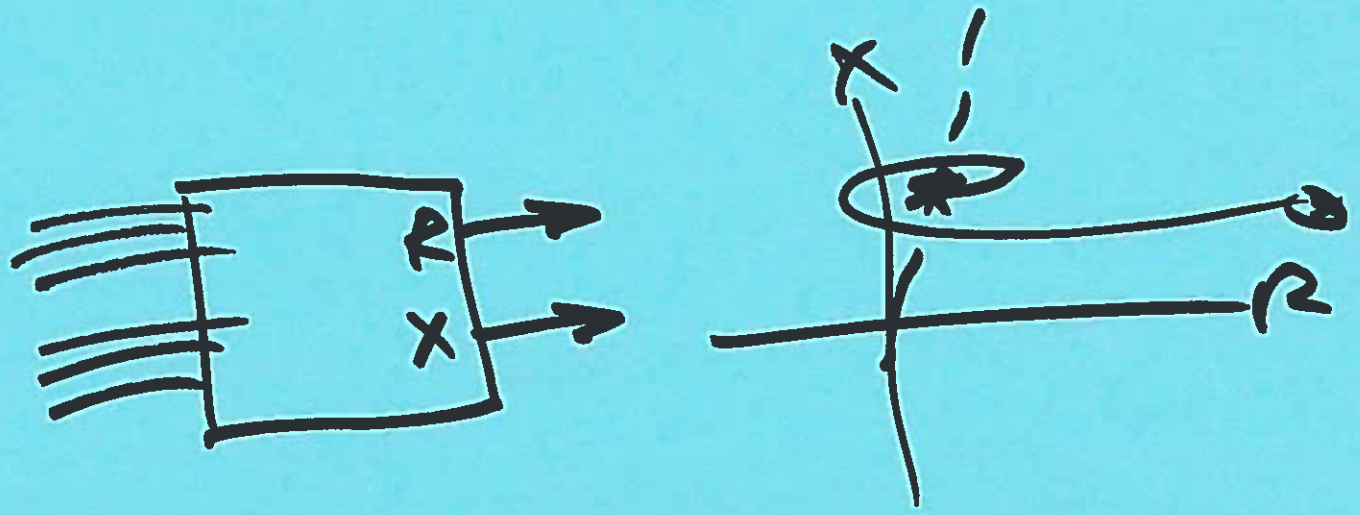
Subtotal (project): _____ / 35

Presentation: _____ / 10

Total: _____ / 45

SMART GRID -


$\tilde{V}_A(t)$
GPS
V_S
I_S
PMU
$\tilde{V}_A, \tilde{V}_B, \tilde{V}_C, \tilde{V}_{A0}, \tilde{V}_{A1}, \tilde{V}_{A2}$
I_S - - - - - -
DFT
Synchrophasors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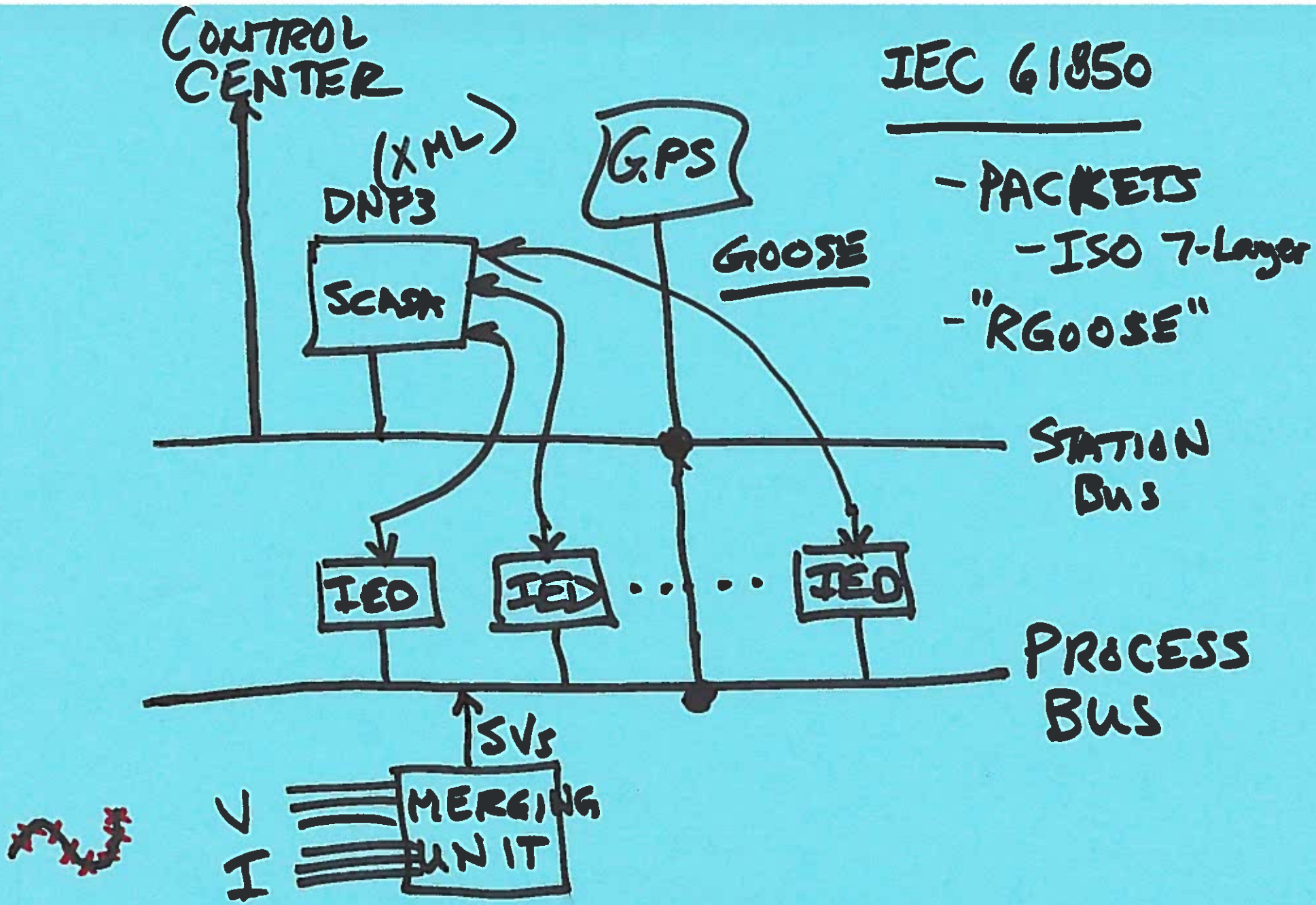


IEC 61850

- PACKETS
  - ISO 7-Layer
- "RGOOSE"

The Future

IEC 61850

- XML tagged data (Next obvious step in SCADA)
- Looks of real-time control of power grid will be like a generic network.
- Cyber-security is big deal.

Security Issues Now:

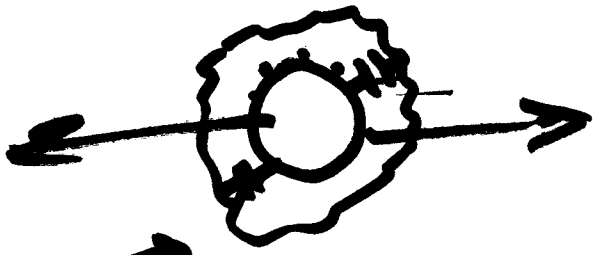
SCADA
- G1: Hard-wired relay-contact control logic.
- G2: "
- G3: µProc.

Protocol Converter
- Relays of various mfrs.
- SCADA Languages
- etc.

Inter-operability

Communications – SCADA, CONTROL, Relaying.

- PLC: Power Line Carrier
  - Couple via CCVT
  - 30 - 450 KHz
    (Usually < 300 KHz if icing)



Transverse Radiation of Signal.

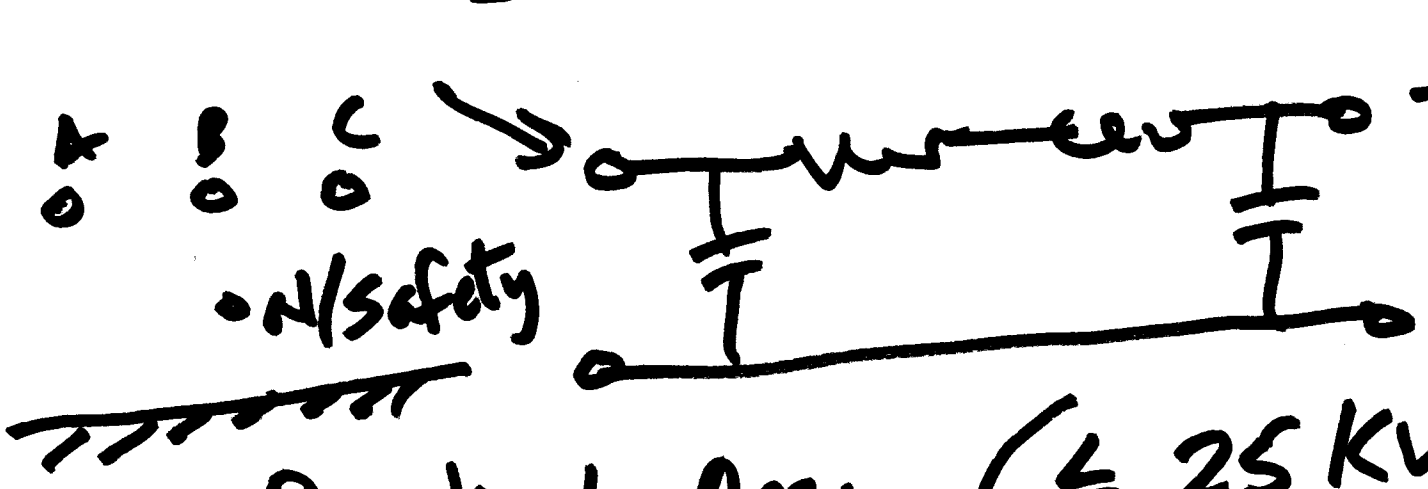
- Fog, Mist: $\vec{E}$ increased
- High-speed, narrow bandwidth
- Dedicated channel, owned by util
- Tends to be very reliable.
- Common use in Sub-Transmission.

Comm (cont'd)

- Leased Line (owned by others)
  - Copper Pair - Ground Pot. Rise.
    - Common in Pilot Schemes.
  - Fiber Optic / MW
- MW - Point-to-point
  - 2 GHz } ← 132 Channels ≥ 30 dB fade margin
  - 6 GHz } — ≥ 40 dB fade margin
  - 10 GHz
- Fiber Optic
  - Inside Shield Wire
  - Wrap - UV / deterioration
  - Buried

- Wireless / Embedded Proc.

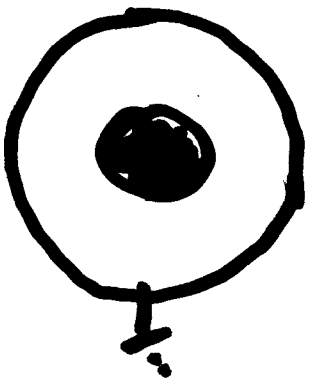
- BPL - Broadband over Power Line
  2 - 30 MHz (up to 80 MHz)



Practical Aps:

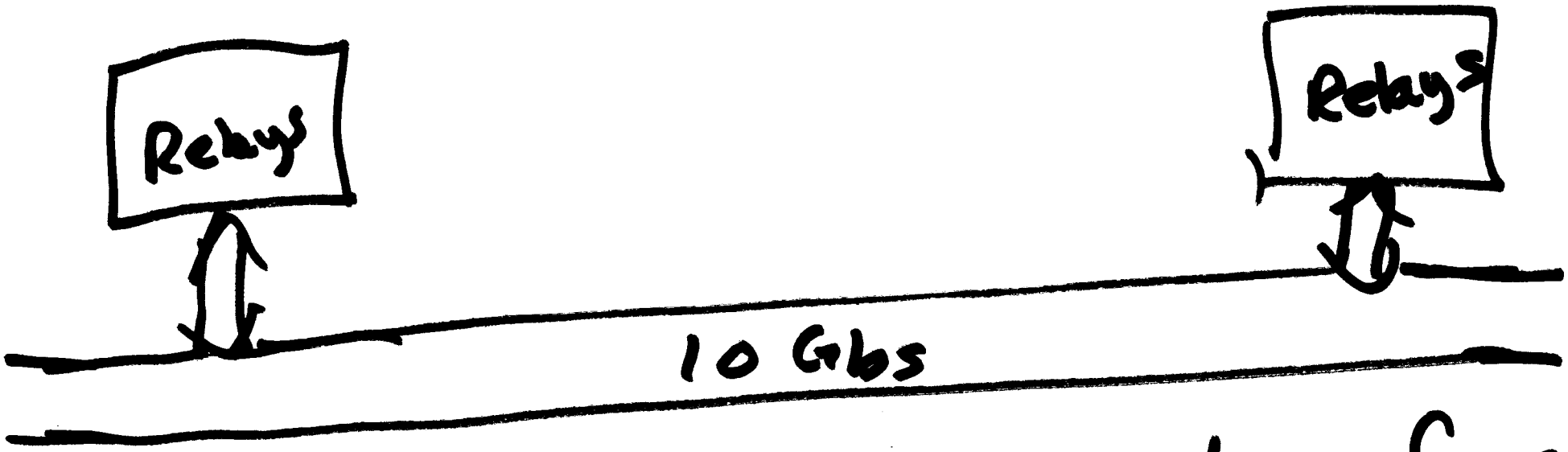
ISPs

- ≤ 25 KV
- ≤ 800 m
- Local Dist, neighborhoods.
- Combined w/ wireless.



Like coat

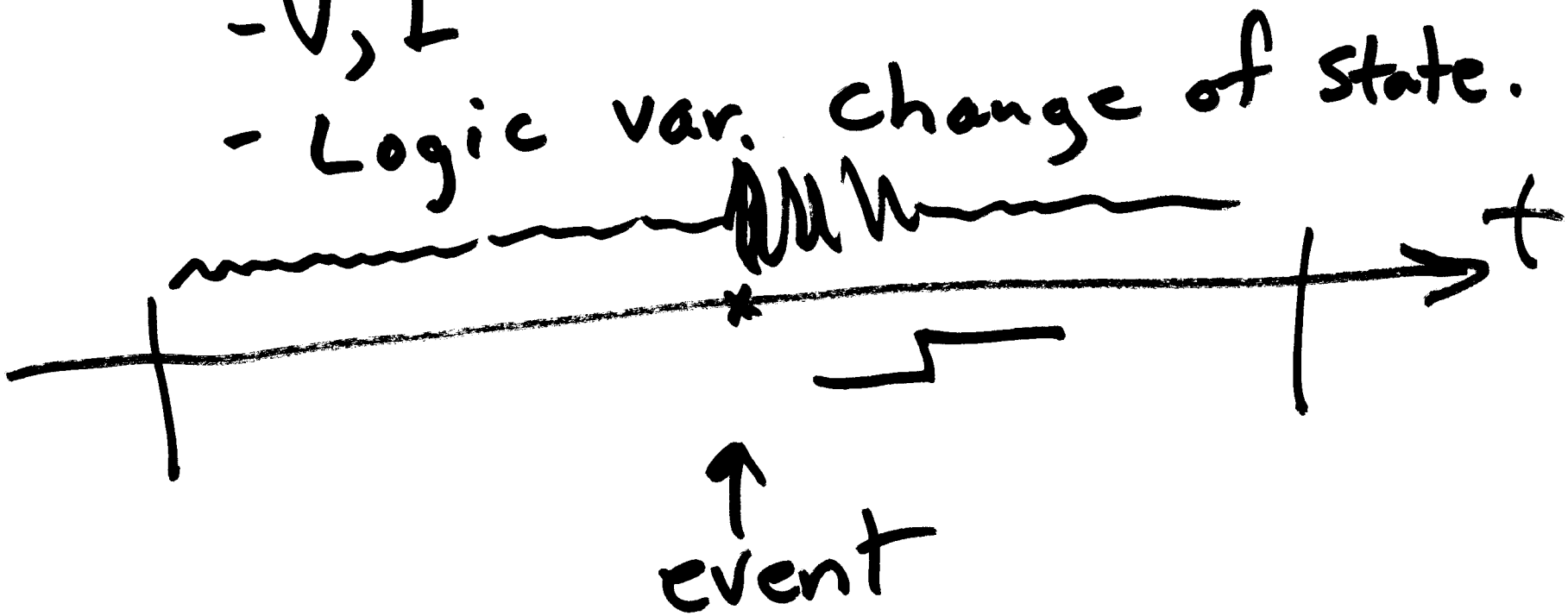
Relay Comm - Peer-to-peer



- Share real-time sampled waveforms
- timing - GPS, time stamp.

Event Recorders – GPS

- V, I
- Logic var. change of state.



SCADA – Comm protocols
- DNP, UCA
- XML

Protocol converter.

Mipsycon F103

TCP/IP – ~4 billion ⇒ IP6