Packet Sniffer for the Physical Layer of the Single Wire Protocol

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Embedded Systems Design
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Outline

1 Motivation
   - Secure Element
   - Single Wire Protocol
   - Packet Sniffing

2 SWP Packet Sniffing System
   - System Design
   - Tapping the Physical Layer
   - Recovering the Interface State
   - Transmitting LLC Layer Packets to the PC

3 Summary and Outlook
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3 Summary and Outlook
Secure Element

- Container for NFC applications
- Applications and data related to a certain user
- UICC already contains subscriber identity module (SIM)
- UICC can be used as the secure element
  - independent of the mobile phone
  - bound to a user identity
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3 Summary and Outlook
Why use the Single Wire Protocol?

- UICC used as the secure element
- Direct interface between the UICC and the CLF necessary
- UICC has only one unused IO pin left
- Major vendors agreed on the Single Wire Protocol
- First devices announced and in production
**What is the Single Wire Protocol?**

- Full-duplex serial communication protocol
- Uses only one IO wire
- Master-to-slave data (S1): voltage domain
- Slave-to-master data (S2): current domain

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### CLF (Master) vs. UICC (Slave)

- **CLF to UICC (S1):** Voltage domain
- **UICC to CLF (S2):** Current domain

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### Figure 4.1: SWP data transmission

- The single wire interface is a bit-oriented, point-to-point communication protocol between a UICC and a contactless frontend (CLF) as shown in the figure.
- The CLF is the master and the UICC is the slave.
Master-to-slave (S1) Signaling

- Voltage domain

- *Disabled*: S1 is constantly low
- *Enabled*: S1 is constantly high
- *Data*: S1 is modulated
  - Pulse width modulation bit coding
  - Logical 1: 75% high, 25% low
  - Logical 0: 25% high, 75% low
  - Variable bit-duration on each transmitted bit
Slave-to-master (S2) Signaling

- Current domain

  - *No data*: S2 is constantly low
  - *Data*: S2 is modulated
    - Non-return-to-zero-level bit coding
    - Current signal is only valid during high-pulses of S1
    - Logical 1: current between 600 and 1000 $\mu$A
    - Logical 0: current between 0 and 20 $\mu$A
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3 Summary and Outlook
Wiretapping and Packet Sniffing

- Tap into wired data link
- Intercept electrical signal
- Analyze the state of the communication
- Receive the data frames
Why is Packet Sniffing useful?

- Analyze communication
- Debug communication problems
  - Framing errors
  - Bit-stuffing errors
  - Checksum errors
  - Problems with the interface state
- Log data traffic
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3 Summary and Outlook
**System Design**

- Discrete tapping circuit
- FPGA-based processing of PHY and MAC layers
- PC-based processing of higher layers
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3 Summary and Outlook
Using an Analog SWP Front-end

- Master connected to a slave’s analog front-end
- Slave connected to a master’s analog front-end
- Intermediate digital signals can be easily tapped

⇒ Induces additional signal delays
⇒ Leads to invalid relation between S1 and S2
Measuring Current and Voltage on SWIO

- Voltage signal S1
  - Directly usable

- Current signal S2
  - Current signal has only between 0.6 and 1 mA
  - Current signal must be transformed into voltage signal
  - Current measurement must not influence the signaling
  - Very low voltage drop required
Measuring Current and Voltage on SWIO

- Ampere meter with low voltage drop transforms current signal into voltage signal
- Analog voltage signals converted to binary digital signals
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3 Summary and Outlook
Recovering the State of the SWP Interface

- FPGA-based processing of the digital versions of S1 and S2
- Decoded into bit-streams based on the interface state (i.e. when S1 is active)
  - S1: high and low phases compared to calculate logical ones and zeros
  - S2: sampled during the high phases of S1
- Bit-streams are then scanned for SWP frames
  - Packet sniffer should be used to debug communication problems
  ⇒ Fault-tolerance required
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3 Summary and Outlook
SWP’s minimum bit-duration is 590 ns

⇒ Each signal has a maximum data throughput of about 1.7 Mbps

⇒ Full-duplex communication is possible

⇒ Data and status information requires up to 4 Mbps
Packet sniffing supports the debugging of SWP applications.

A promising measurement circuit has been found.

Outlook

- The evaluated circuit has to be tested with bit-durations up to 590 ns.
- The system has to be tested with real SWP devices outside the test environment.