Secure Data Export and Auditing using Data Diodes

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http://www.cs.uiowa.edu/~jones/voting/diode/
The Problem

- Election result must be put on the net.
- Election database must be protected.
- Conflict resolved by:
  - Sneakernet or
  - Even odder solutions

Miami Dade County Solution
Security through obscurity
What we need

A data diode

- Allow data export
- Prevent data import
- Design understood by
  - Election observers
  - Election officials
  - Losing candidates
• Claims limited to up-hierarchy transmission
• Example given for RS-232 implementation
  – Transmit: 1 IC + 8 components + 5 volt supply
  – Receive: 1 IC + 4 components + 5 volt supply
• Explain this to a naïve suspicious observer!
Commercial Data Diodes

- Both based on fiber-optic technology
- Tenix Data Diode certified to EAL 7 under Common Criteria

www.owlcti.com

www.tenix.com
Design Transparency

- EAL 7 certification
  - Insufficient if the certifying agency is not trusted
  - What if the vendor cheats after certification?
- Therefore, we need
  - Complete design transparency
  - Open documentation
  - Rights of observers to inspect entire mechanism
  - Minimal complexity
Our Design

- Avoid all black boxes
  - no 3-terminal devices
  - No ICs
- Extreme simplicity
  - Use RS-232
Explaining the circuit board

- Must explain function of
  - Every circuit trace
  - Every component
Explaining the Transmitter

- **GND**: signal ground
- **TxD**: transmit data
- When **TxD** is positive
  - Top LED lights
- When **TxD** is negative
  - Bottom LED lights
- **Resistor needed as**
  - Current limiter
Explaining the Transmitter

- The shield pin in the cable
  - Connects to metallic sheath
- The shield pin on the board
  - Connects to trace that surrounds the electronics
- Together
  - These make it difficult to use conductors inside the shield as radio antennas
Explaining the Transmitter

- The loopback connections
  - Tell computer we're ready

- RTS to CTS
  - Request To Send (input)
  - Clear To Send (output)

- DTR to DSR and DCD
  - Data Terminal Ready (input)
  - Data Set Ready (output)
  - Data Carrier Detect (output)
Explaining the Receiver

- The power supply
  - Uses RTS TxD and DTR
- Power from Serial cable
- Power from special cable
  - 2 batteries
  - AC power from wall outlet
- Capacitors and Diodes
  - Permit 60Hz operation
Explaining the Receiver

- The Receiver itself
  - Uses the power supply
  - Transmits to RxD output
- Top photodiode
  - Pulls RxD positive
- Bottom photodiode
  - Pulls RxD negative
- Resistors needed as
  - Current limiters
Using the Data Diode

- No reverse channel (almost)
  - Must rely entirely on forward error correction
  - Checksums (or better) to reject bad data
  - Redundancy to provide for correction
  - Operational status determined from downstream

- Sending from high to low security domain
  - Covert content in data is a big issue
  - Unlike most low to high transmission
Auditors and Wiretaps

- Data exported from EMS is public
- Observers should not trust the web server
- So, observers should be allowed wiretaps
  - Directly observe data-flow to server
  - Directly verify that data conforms to spec
- Free air (as opposed to fiber optic) optical data diodes offer excellent access to the data stream by observers!
Exporting Election Results

Using relational database terminology, election results are a single relation over:

- Precinct (or split, for split precincts)
- Race (or contest)
- Candidate (or position with respect to contest)
- Votes for that candidate in that race in that precinct

What we need to do is export this entire relation
OASIS EML, A Bad Idea

- Requires header
  - Data diode invites an infinite stream
- Verbose
  - Human audit difficult
- Covert channels
  - Complex rules for canonical form
- Difficult to checksum
Reasonable Data Formats

- A repeating stream of checksummed records
- Tab separated fields?

IC15 President Lincoln 25 16384
CV06 Mayor Thomas 42 32768

- XMLish but not really XML

```xml
<ITEM PRECINCT="IC15" RACE="President" CANDIDATE="Lincoln" VOTES="25" />
```

```xml
<ITEM PRECINCT="CV06" RACE="mayor" CANDIDATE="Thomas" VOTES="42" />
```

- We opt (on weak grounds) for XMLish
Covert Channels

• The Risk
  – Covert export of security keys from EMS

• The Defense
  – Rigid format constraints on data
    • No optional, permutable, or alternate elements
    • No free use of whitespace or line ends
  – Code audit on real-time checks in transmit code
    • No non-constant time delays allowed in transmitter
Transparent Checksums

- We have a transparent data diode design
- We have a transparent data format
- We need a transparent checksum algorithm
  - Understandable using highschool math
  - Easy to code in a bad programming language
- CRC-16 is not transparent!
  - Try explaining this: $X^{16} + X^{15} + X^2 + 1$
  - Or this:
Transparent Checksums

• A classic transparent but weak checksum
  \[ S_0 = 0; S_{i+1} = (S_i + C_i) \mod 256 \]

• A modest proposal
  \[ S_0 = 0; S_{i+1} = (5S_i + C_i) \mod 65536 \]
  
  – Akin to multiplicative congruence PRNG

• What multipliers and moduli are best

• Is there a cryptographically secure hash code that meets our transparency goals?
```c
#include <stdio.h>
/* filter to checksum each block of angle-bracketed text
   Reads from stdin and copies to stdout.
   Appends decimal checksum to each closing angle bracket.
   Angle brackets are included in the checksum.
   NOTE: This code is dumb, bracket nesting is ignored and
   bracked imbalance is not checked. */
main ()
{
  int ch;
  unsigned int sum = 0;
  while ((ch = getchar()) != EOF) {
    putchar( ch );
    sum = (sum * 5 + ch) % 66636; /*accumulate*/
    if (ch == '<') {
      sum = '<'; /*initialize*/
    } else if (ch == '>') {
      printf("%lu",sum);
    }
  }
}
Even this is hard to explain, but it's in reach of a student who
only has a semester of programming, perhaps in VB or worse
A Prototype Application

- Scaffolding
  - Extract results from example county data
  - Inject in model EMS database
- Demo code
  - Cyclically scan EMS database
  - Export through data diode
- Decent quality prototype application code
  - Receive data from data diode to mirror database
  - Server-side web application for results
Other Applications

- Upstream

- In voting machine