Center for Embedded Networked Sensing

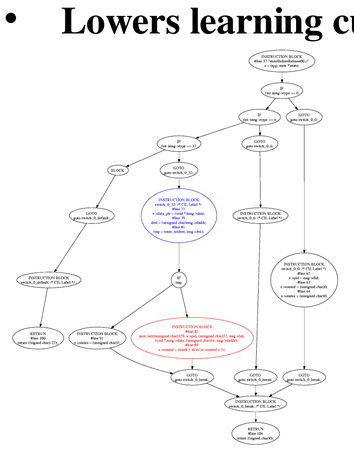
Static Analysis of Bottom Tier Sensor Networks

Roy Shea, Todd Millstein, Rupak Majumdar, and Mani Srivastava
Software Systems Laboratory and Networked and Embedded Systems Laboratory

Motivation: Bringing Accessible Static Analysis To Sensor Network Development

Static Analysis is Cool

- Has the potential to find bugs before they arise
- Streamlines the development process
- Lowers learning curve for new developers

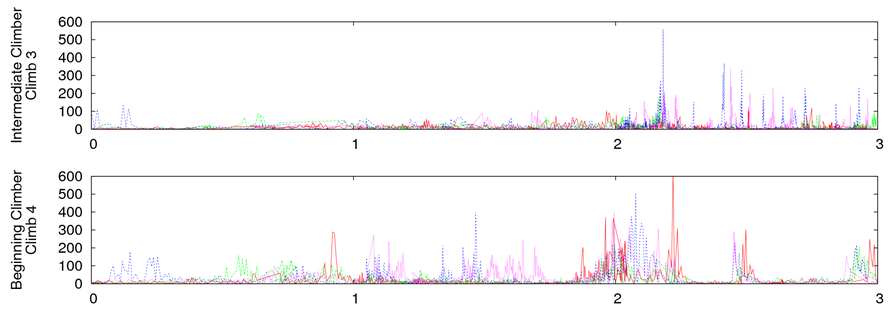


Bottom Tier Sensing Devices are Cool

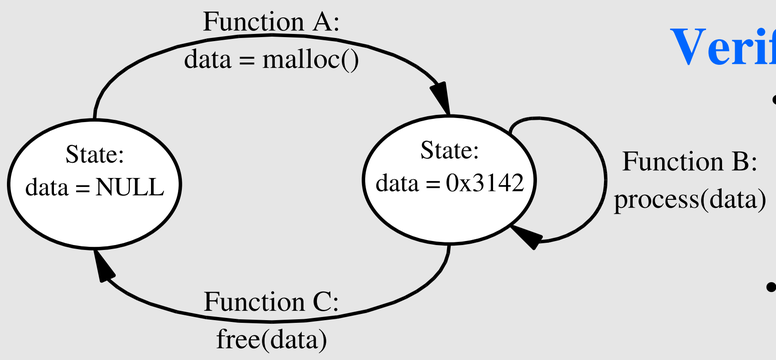
- Developer can look at the entire system
- All-in-one hardware is great for hobbyist and students
- Show you amazing things about the world we live in

Combination of These?

- **Difficulties developing sensor network applications**
  - Limited insight into a running system
  - Common failure mode is simply “not working”
  - Failures are not well contained
- **Desire gaining insight into bottom tier sensing devices by applying static analysis**

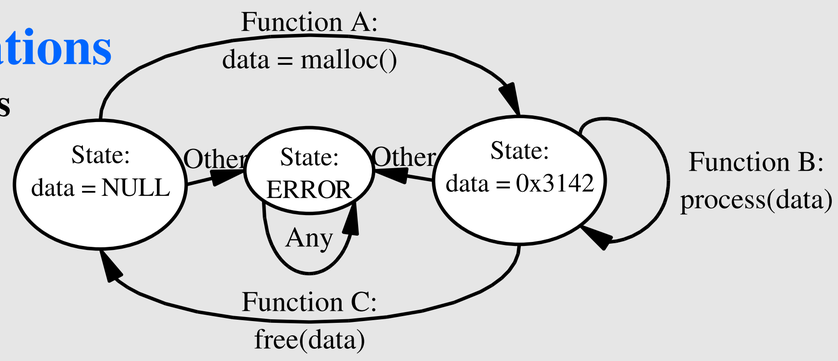


Problem: Mapping Traditional Analysis Onto Very Reactive Systems



Verifying Sensor Network Applications

- **Event handlers react to external events**
  - Sensor detects an event of significance
  - Message is received over the radio
  - Timer injects event into the system
- **Naïve model assumes any event can occur at any time**



Proposed Solution: Drive Static Analysis with Ordering Specifications

Lighthouse

- **Simple exclusive resource ownership model**
  - All heap memory is owned by exactly one module
  - Owner is responsible for releasing the memory or transferring it to another module
  - Modules may not free or transfer ownership of heap data that they do not own
- **Uses standard dataflow techniques to verify each function**
  - May / must pointer analysis used to resolve aliases
  - Function summaries used to handle function calls

Verified Memory Leaks	8
False Memory Leaks	8
Verified Dangling Pointers	0
False Dangling Pointers	9

Warnings generated from the analysis of 213 unique versions of SOS modules totalling 28042 SLOC

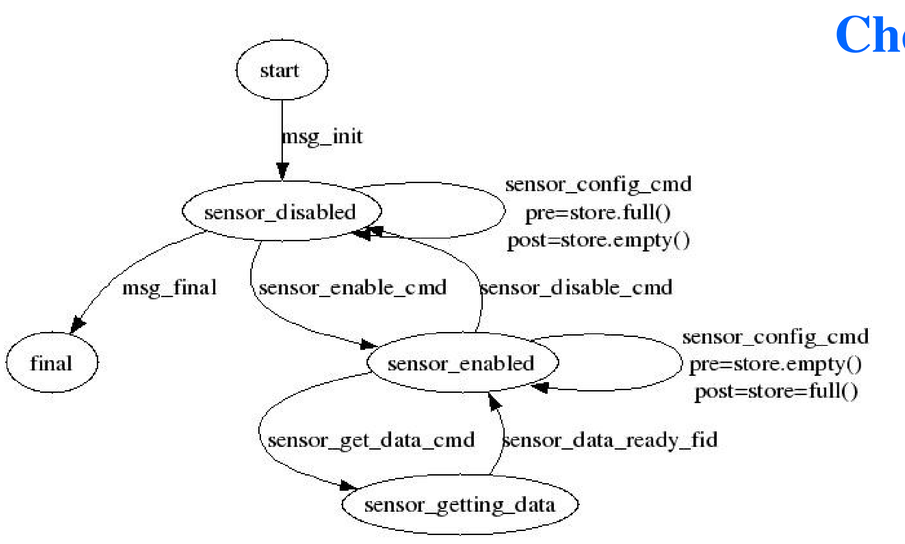
Verified Memory Leaks	2
False Memory Leaks	22
Verified Dangling Pointers	0
False Dangling Pointers	11

Warnings generated from the analysis of 40 source files making up the SOS kernel totalling 9223 SLOC

```
mod_op = (sos_module_op_t*) ker_msg_take_data(msg);
if(mod_op == NULL) return -ENOMEM;
if(mod_op->op == MODULE_OP_INSMOD) {
    existing_module = ker_get_module(mod_op->mod_id);
    if(existing_module != NULL) {
        uint8_t ver = sos_read_header_byte(...);
            if (ver < mod_op->version) {
                ker_unload_module(...);
            } else {
                return SOS_OK;
            }
        }
    ret = fetcher_request(KER_DFT_LOADER_PID,
            mod_op->mod_id, mod_op->version,
            entohs(mod_op->size), msg->saddr);
    s->pend = mod_op;
    ker_led(LED_RED_TOGGLE);
    return SOS_OK;
}
return SOS_OK;
```

```
Error: Expression mod_op is not stored after
   instruction #line 125
mod_op = (sos_module_op_t*)
   ker_msg_take_data((unsigned char)18, msg);
```

Checkpoint



- **Static analysis driven by finite state machine specification**
- **Specification provided by the developer describes correct execution of a program**
  - Set of arbitrary states associated with specific source code
  - Set of events that cause transitions between states
  - Persistent store pre- and post- conditions for stores when a specific event causes a transition between two states
- **Critical for the reactive sensing environments**
- **Checkpoint used to refine the Lighthouse analysis**

Future Work

- **Specification inference**
  - Infer memory manipulation within individual functions
  - Infer interfunction per- / post- state dependencies
- **Finite state machine specification**
  - What is the best way to describe the FSM?
  - Transitioning from functional specification to slice-oriented specification