Cyber Security Research Centre

Lancaster University

Academic Centre of Excellence In Cyber Security Research

in association with National Cyber Security Centre

Automating Threat Modelling

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Introduction

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Research focus:

- Cyber Security and Privacy
- Computing devices with limited resources (e.g., IoT)
- Context Privacy – How the actions a system takes reveals important information to an adversary

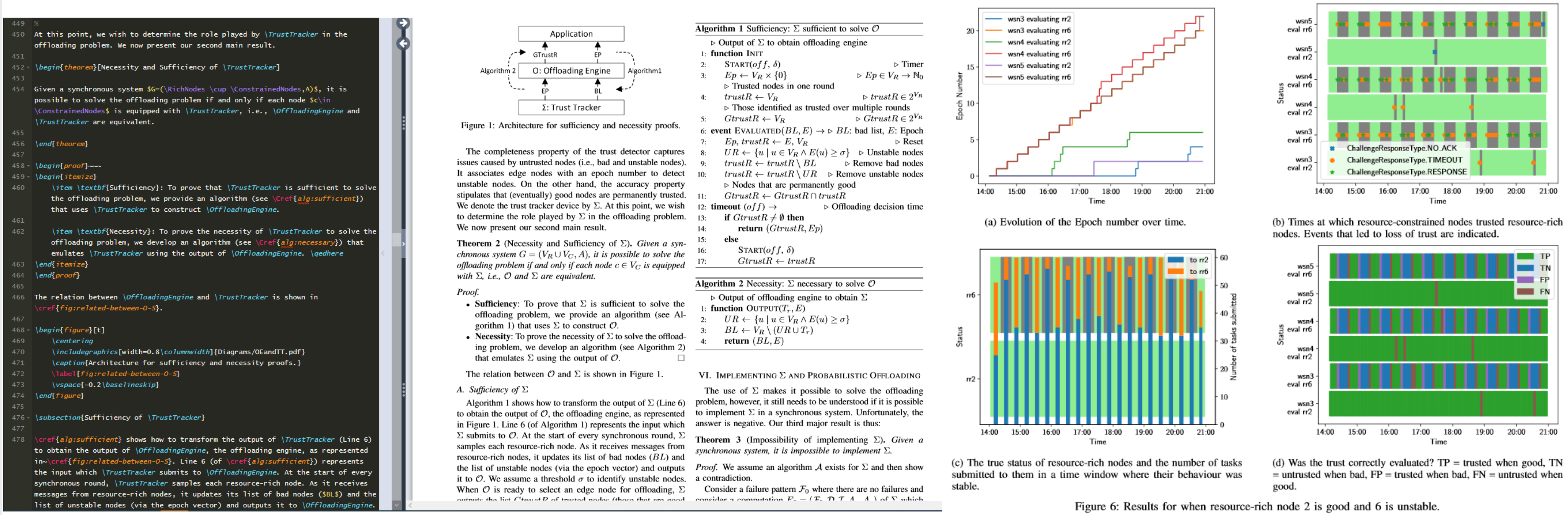
What is Academic Research?

Expectation: Write Code

```c
float calculate_trust_value(edge_resource_t* edge, edge_capability_t* capability)
{
    // Get the stereotype that may inform the trust value
    edge_stereotype_t* s = NULL;
    public_key_item_t* item = keystore_find_addr(&edge->ep.ipaddr);
    if (item != NULL)
    {
        s = edge_stereotype_find(&item->cert.tags);
    }

    float trust = 0;
    float w_total = 0;
    float w, e;

    beta_dist_t temp;

    w = find_trust_weight(capability->name, TRUST_METRIC_TASK_SUBMISSION);
    beta_dist_combine(&edge->tm.task_submission, s ? &s->edge_tm.task_submission : NULL, &temp);
    e = beta_dist_expected(&temp);
    trust += w * e;
    w_total += w;

    w = find_trust_weight(capability->name, TRUST_METRIC_TASK_RESULT);
    beta_dist_combine(&edge->tm.task_result, s ? &s->edge_tm.task_result : NULL, &temp);
    e = beta_dist_expected(&temp);
    trust += w * e;
    w_total += w;

    w = find_trust_weight(capability->name, TRUST_METRIC_RESULT_QUALITY);
    e = beta_dist_expected(&capability->tm.result_quality);
    trust += w * e;
    w_total += w;
```

```python
class Simulator:
    def __init__(self, seed: int, agents: List[Agent], escls, duration: float, utility_targets: UtilityTargets, log_level: int):
        # Initialise the PRNG and record the seed
        self.seed = seed
        self.rng = random.Random(self.seed)

        self.agents = agents
        for agent in self.agents:
            agent.set_sim(self)

        self.es = escls(self)

        self.duration = duration
        self.utility_targets = utility_targets

        self.current_time = 0
        self.queue = []

        self.metrics = Metrics()

        self.log_level = log_level

    def add_event(self, event):
        heapq.heappush(self.queue, event)

    def run(self, max_start_delay: float):
        # Add start event
        for agent in self.agents:
            self.add_event(AgentInit(self.rng.uniform(0, max_start_delay), agent))

        while self.queue:
            item = heapq.heappop(self.queue)

            assert item.event_time >= self.current_time

            # Has the simulation finished?
            if item.event_time > self.duration:
                break

            self.current_time = item.event_time

            item.action(self)
```

Reality: Developing new theory



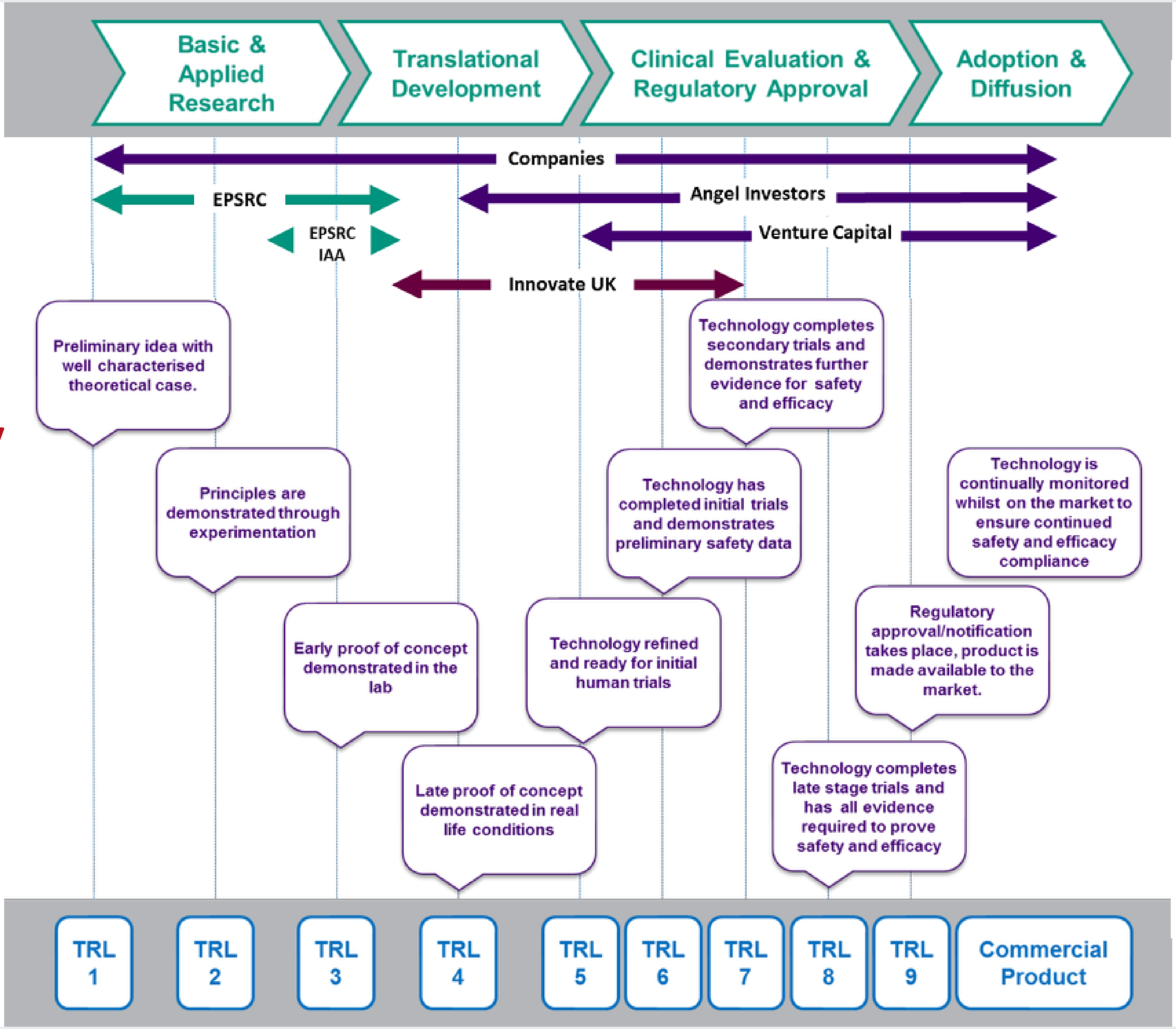
Reality: Experimentation, Outreach, …

Academic Research

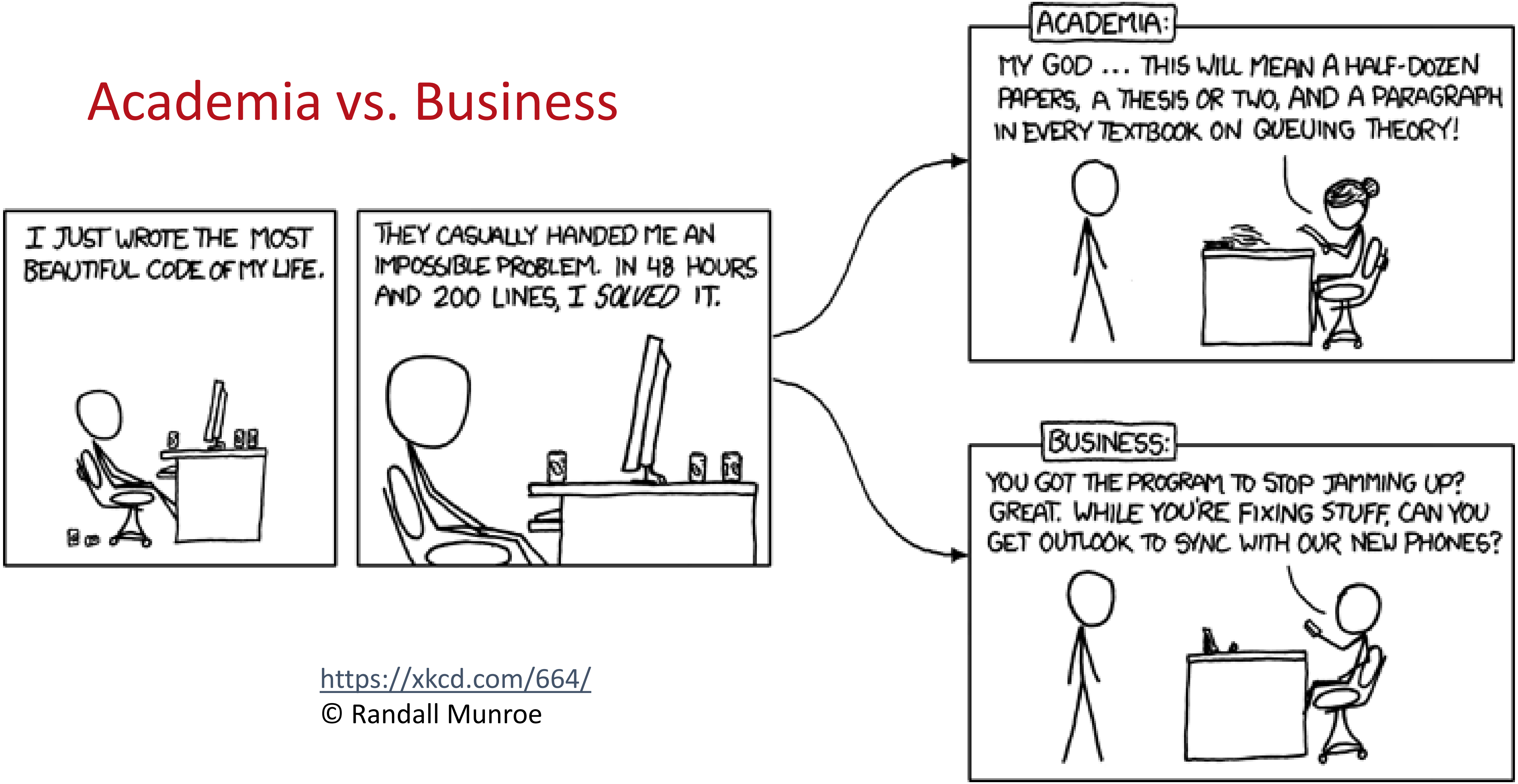
Identify and address **novel** problems

- Novel – a **new** problem, a **new** and **better** solution
- We tend not to focus on engineering activities
- Our work may incorporate building a system, but also:
  - Quantification of security / privacy / performance
  - Formal modelling to prove security / privacy of a system
  - Experimentation and analysis on a system

Technology Readiness Levels



Academia vs. Business



https://xkcd.com/664/

Engaging with Academia

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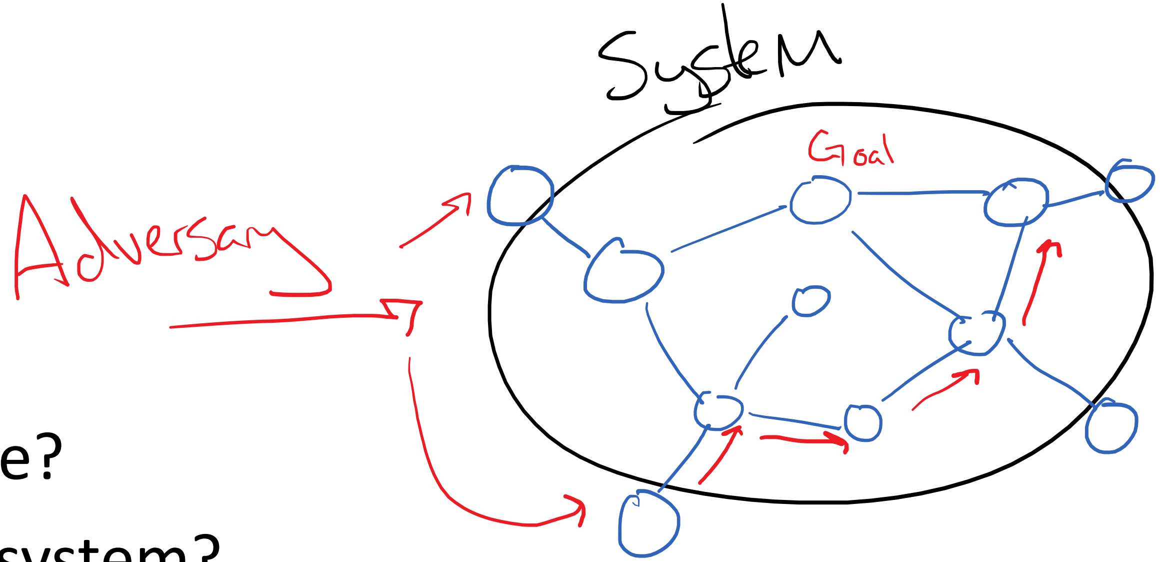
- Student Projects (Both UG and PG)
- Summer internships
- Knowledge Transfer Partnerships & Other Innovate UK Funded Initiatives
- Consultancy
- Contract / Collaborative Research
- CASE Studentship Sponsorship
- PhD students
- & More

Automating Threat Modelling

What is Threat Modelling

You have a system:

- How can an adversary attack it?
- What goals might the adversary have?
- What path does it take through the system?
- How does it compromise different components of your system?



Threat Modelling tends to be Manual

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Define the system

Do you know all components in your system?

↓

What is your adversary, what are their capabilities, TTPs, …

↓

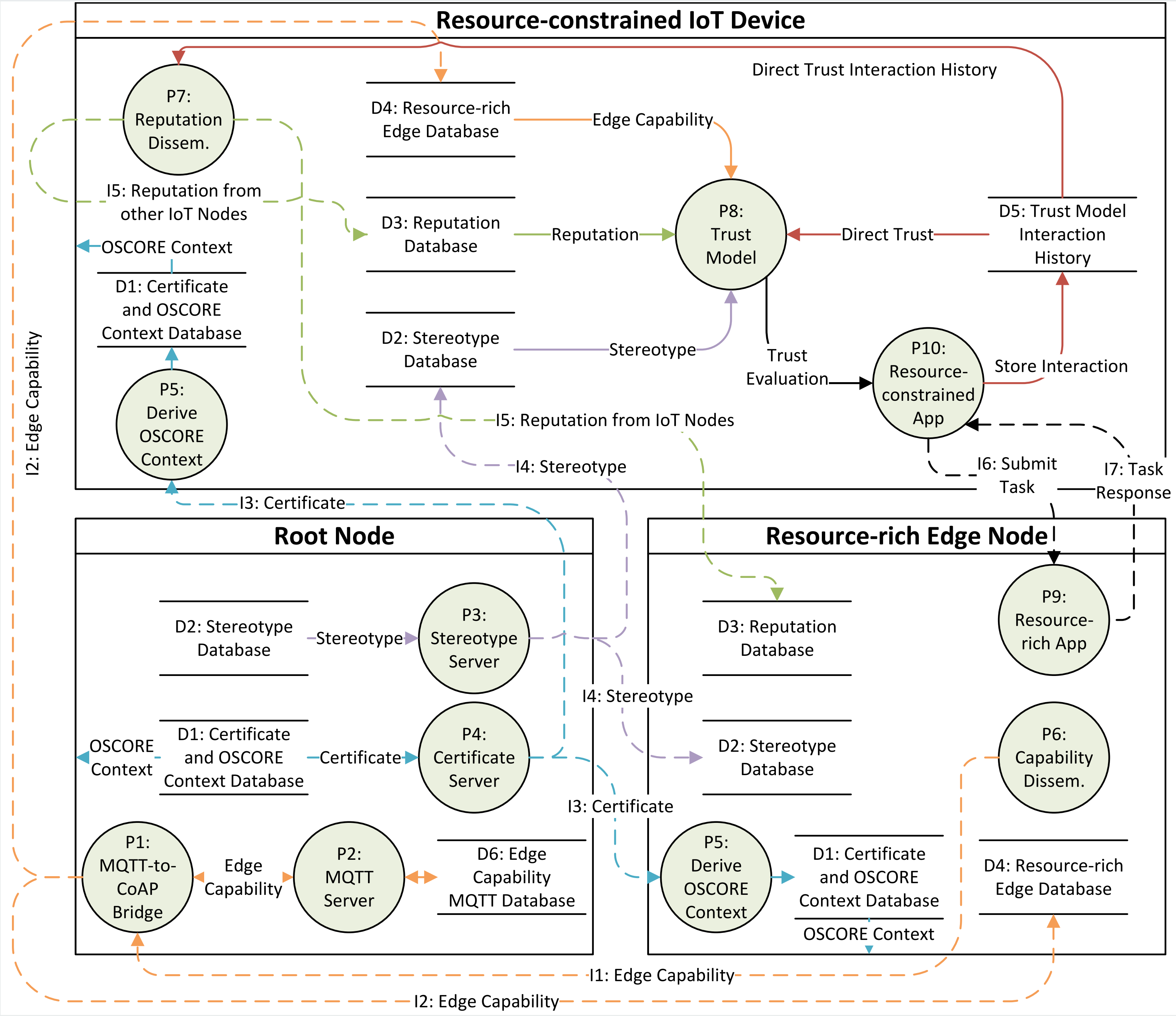
Identify how each component can be attacked

How do you know the component can be attacked in this way?

↓

What path does the adversary take through the system to reach its goal?

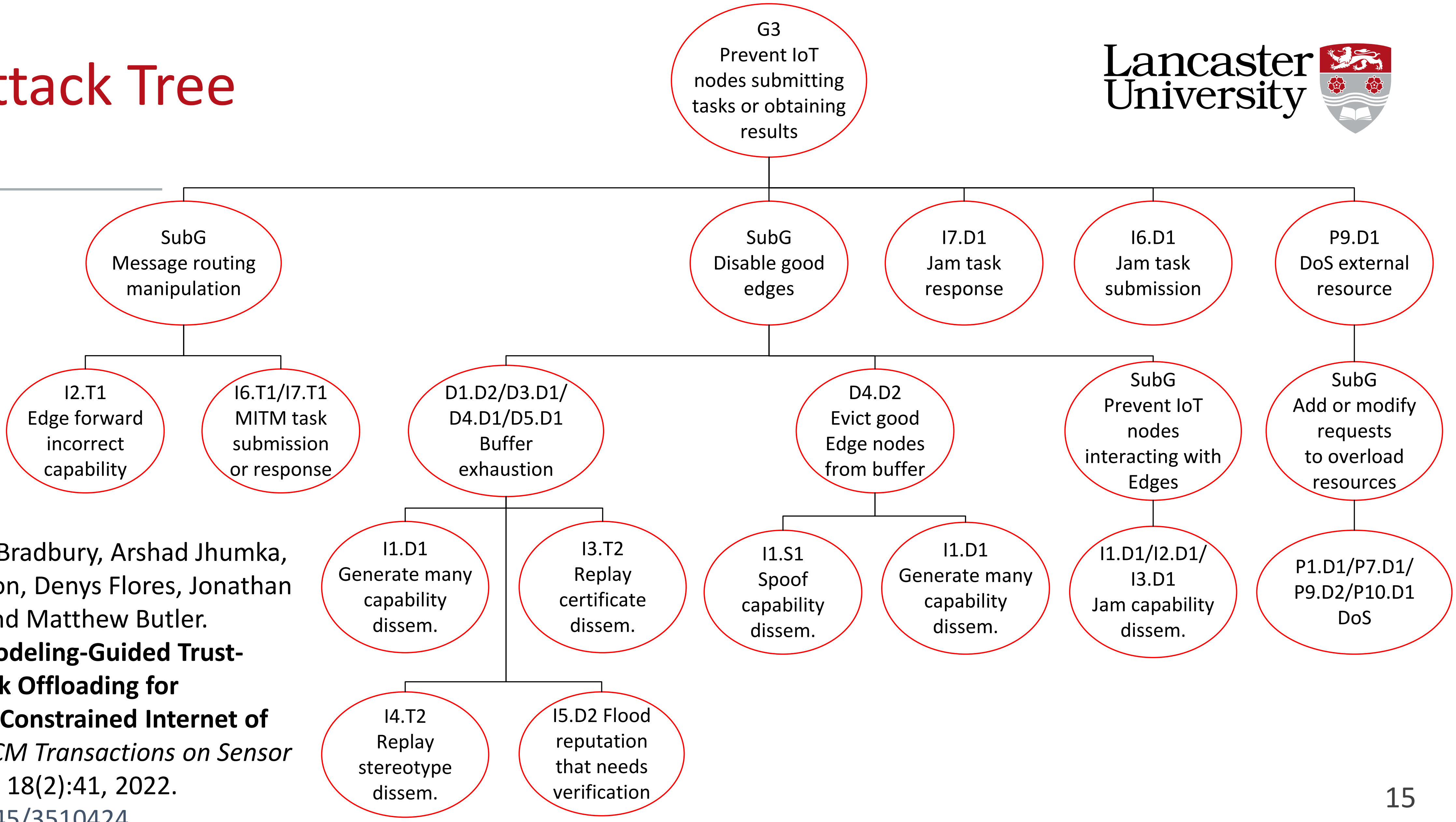
How do you know what an adversary is capable of after a compromise?



Data Flow Diagram

- Resource-constrained IoT devices offloading tasks to resource-rich Edge nodes
- What data is used to assess a measure of *behavioural trust* in an Edge node performing a task?

Attack Tree



Matthew Bradbury, Arshad Jhumka, Tim Watson, Denys Flores, Jonathan Burton, and Matthew Butler. **Threat-Modeling-Guided Trust-Based Task Offloading for Resource-Constrained Internet of Things**. *ACM Transactions on Sensor Networks*, 18(2):41, 2022. doi:10.1145/3510424.

Existing Automatic Tools

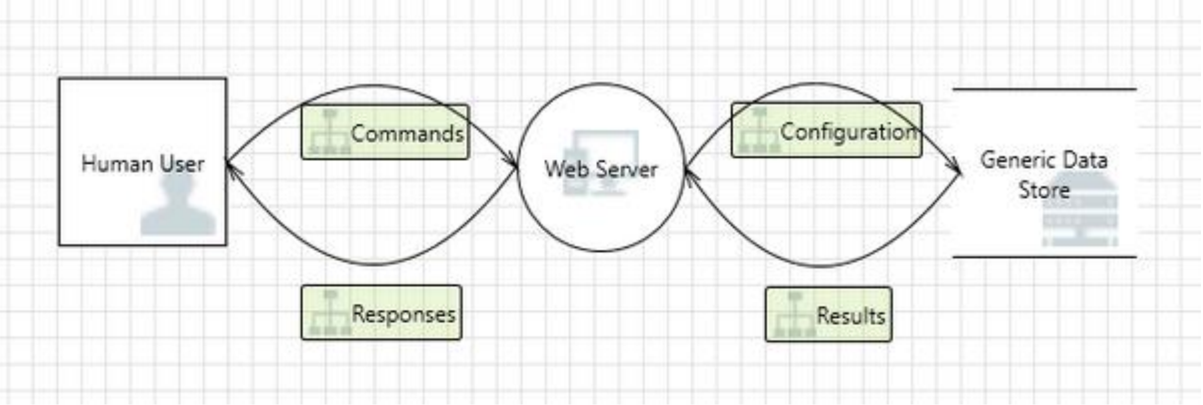
- Automatic threat modelling tools exist!
- Typically aim to solve the problem of:
  "Identify how each component can be attacked"

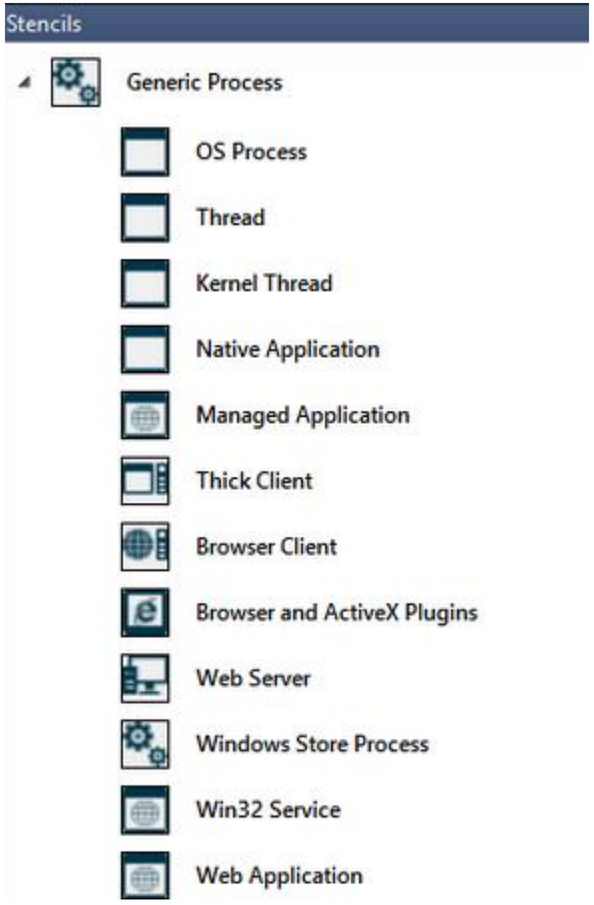
```
"SID": "INP02",
"target": [
  "Process"
],
"description": "Overflow Buffers",
"details": "Buffer Overflow attacks target improper or missing bounds checking on buffer
    operations, typically triggered by input injected by an adversary. As a consequence, an
    adversary is able to write past the boundaries of allocated buffer regions in memory,
    causing a program crash or potentially redirection of execution as per the adversaries'
    choice.",
"Likelihood Of Attack": "High",
"severity": "Very High",
```

https://github.com/izar/pytm/blob/master/pytm/threatlib/threats.json

Existing Automatic Tools

- Typically these tools have pre-defined components
- You can define that these components interact
- The tool then produces threats against individual components





https://docs.microsoft.com/en-us/azure/security/develop/threat-modeling-tool-getting-started

The Problem

- How do we answer:
  “What path does the adversary take through the system to reach its goal?”
- Challenging to do realistically with tools targeting high-level and low-level abstractions

- Do these tools tell us useful information?
- Do they just tell us about known attack vectors instead of discovering new ones?

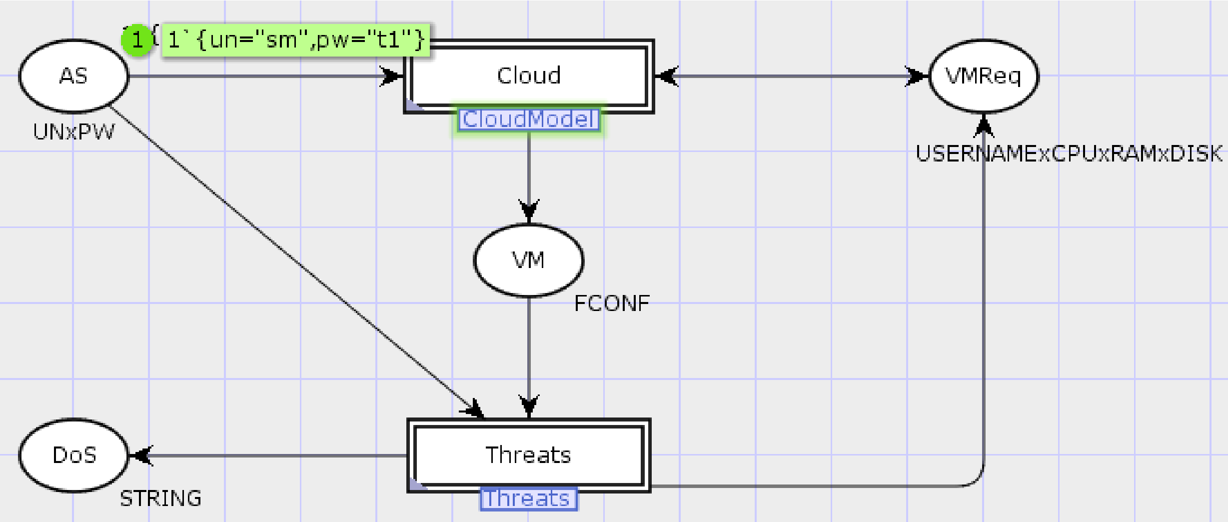
Scope for Academic Research

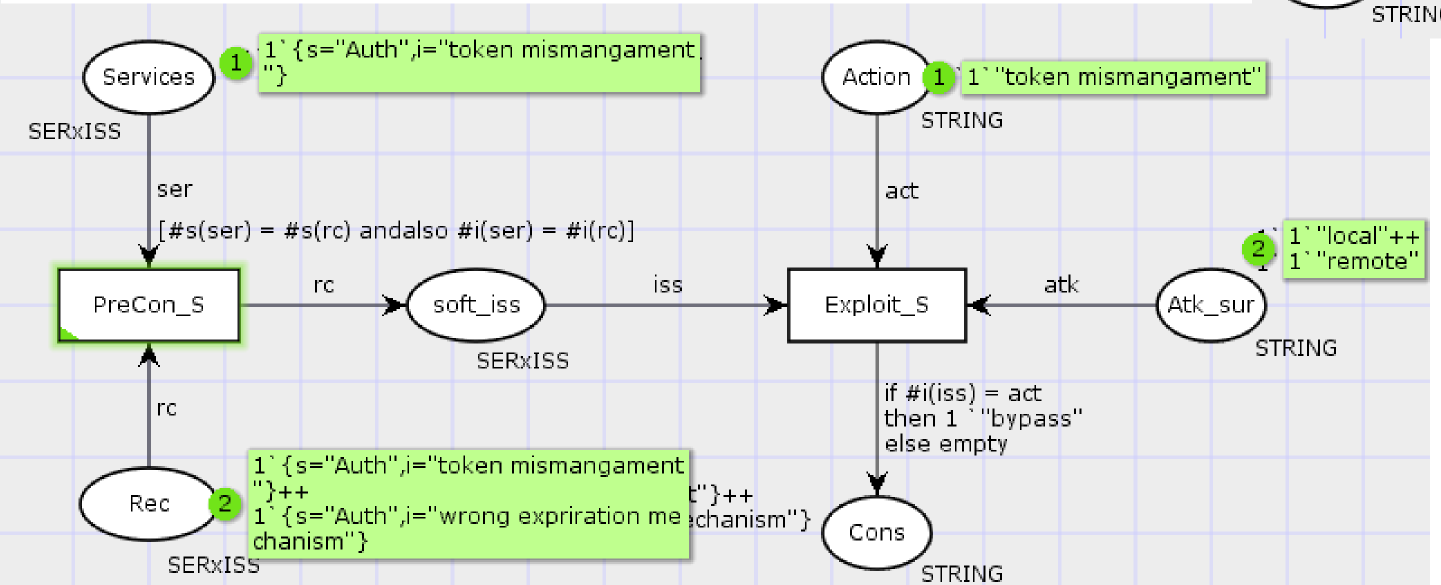
- Research questions:
  - How do we describe a system at the appropriate level?
  - How do we model adversary capability escalation?
  - Can we describe past attacks?
  - Can we speculate on future possible attacks?

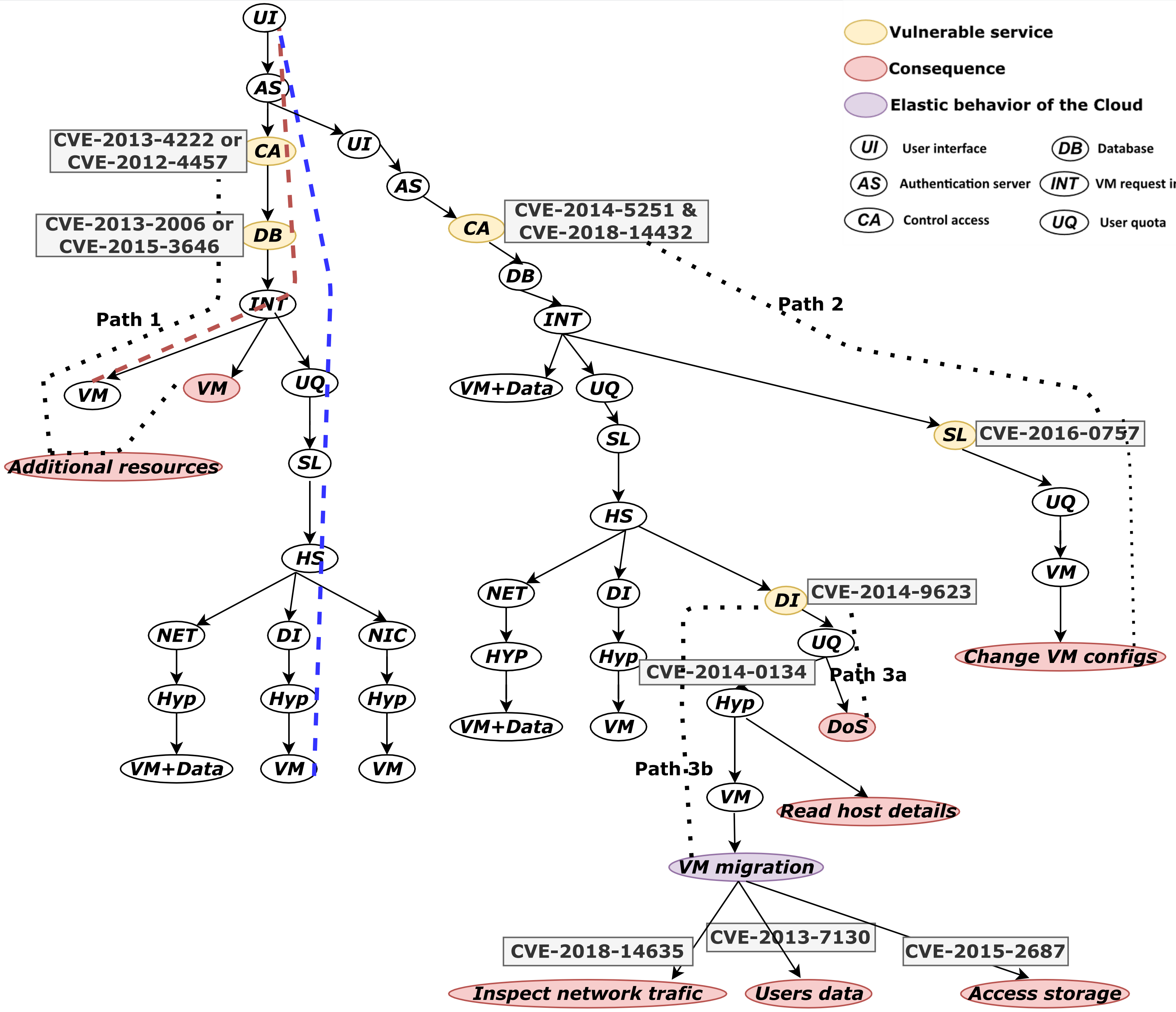
- Make the model arbitrary – suitable for general systems

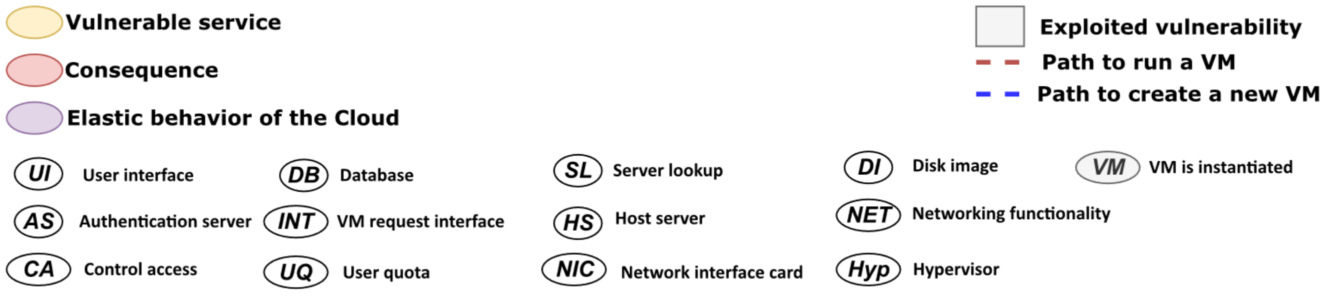
Some preliminary work

Model the system and adversary using Petri nets









- Analyse previous attacks
- Speculate on potential avenues for attack

More to be done

- Research questions:
  - How do we describe a system at the appropriate level? ✓
  - How do we model adversary capability escalation? Not yet
  - Can we describe past attacks? ✓ (partially)
  - Can we speculate on future possible attacks? ✓ (partially)

- The cost of creating these models is high - can we automate this process?
- How can cyber physical systems be considered?

References

- https://www.oreilly.com/library/view/threat-modeling/9781492056546/ch04.html
- https://github.com/threatspec/threatspec
- https://docs.microsoft.com/en-us/azure/security/develop/threat-modeling-tool-threats
- https://github.com/izar/pytm
- https://owasp.org/www-project-threat-dragon/

Thank you for watching!

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Matthew Bradbury is a Lecturer conducting research into security, context privacy and trust assessment in resource-constrained and distributed systems.

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