Cadence - A Simulator for Human Movement-based Communication Protocols

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Motivation

Motivation

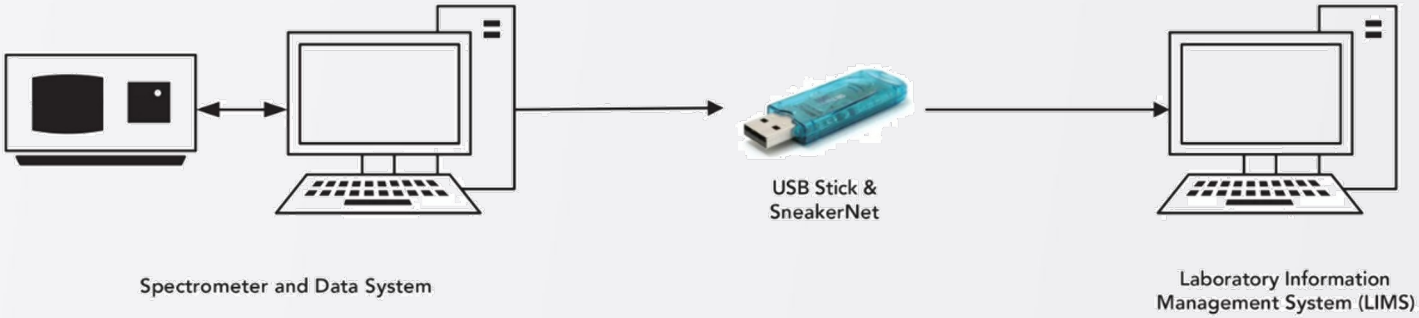
- 64% of internet users express concern over governmental censorship (Go Globe).
- The Internet can be disrupted in times of crisis, either due to natural (e.g., natural disasters) or human causes (e.g., war).

Anti-Censorship Methods

- Alternate names and addresses (DNS)
- Mirrors, Proxies
- Traffic obfuscation
- Sneakernets

Sneakernets

- USB/BLE/NFC/Mesh Wifi



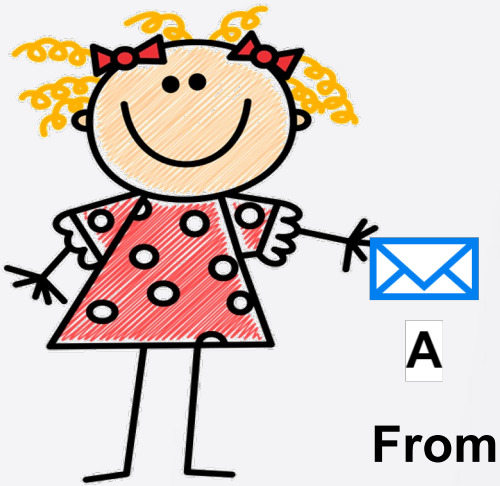
- Encounters between physical devices.
- The most well known uses of sneakernets were in Iraq and Hong Kong, 2014.

FireChat

Why Sneakernets?

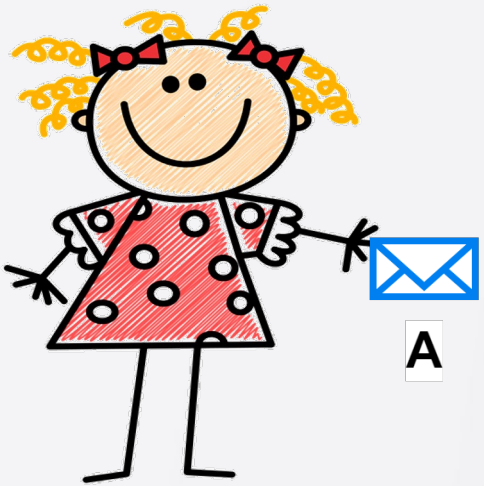
- Bypassing Internet Censorship
- Anonymity and Privacy
- Limited Digital Footprint
- Reduced Dependency on Online Infrastructure

Sneakernets – How it works?



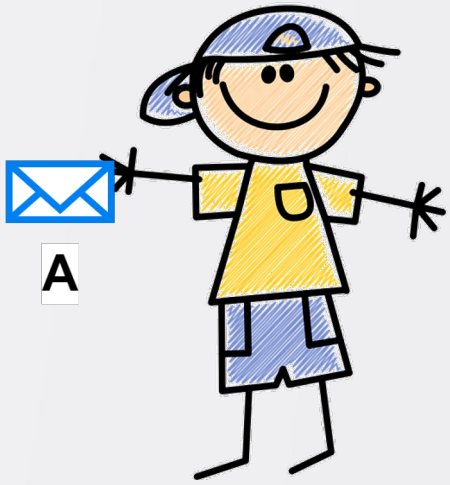
From: Alice
To: Charlie
Content: Let's go outside!

Sneakernets – How it works?



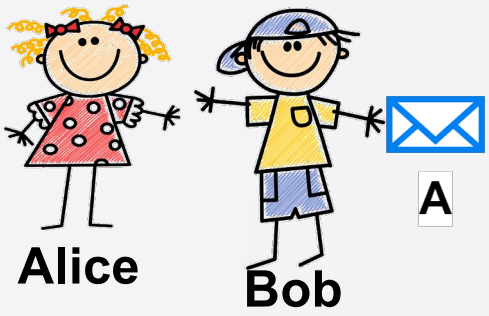
Sneakernets – How it works?

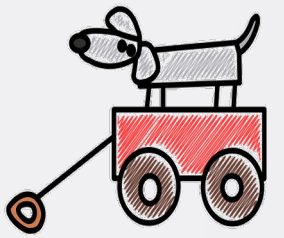
Alice



Bob

Sneakernets – How it works?





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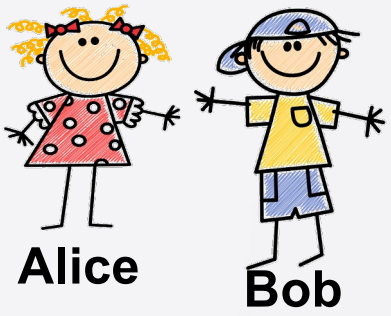
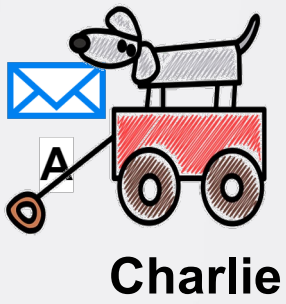
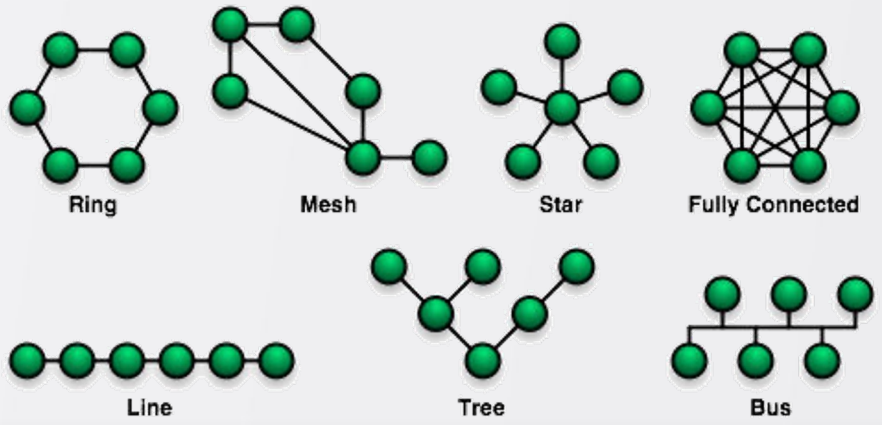




Charlie

Open Questions

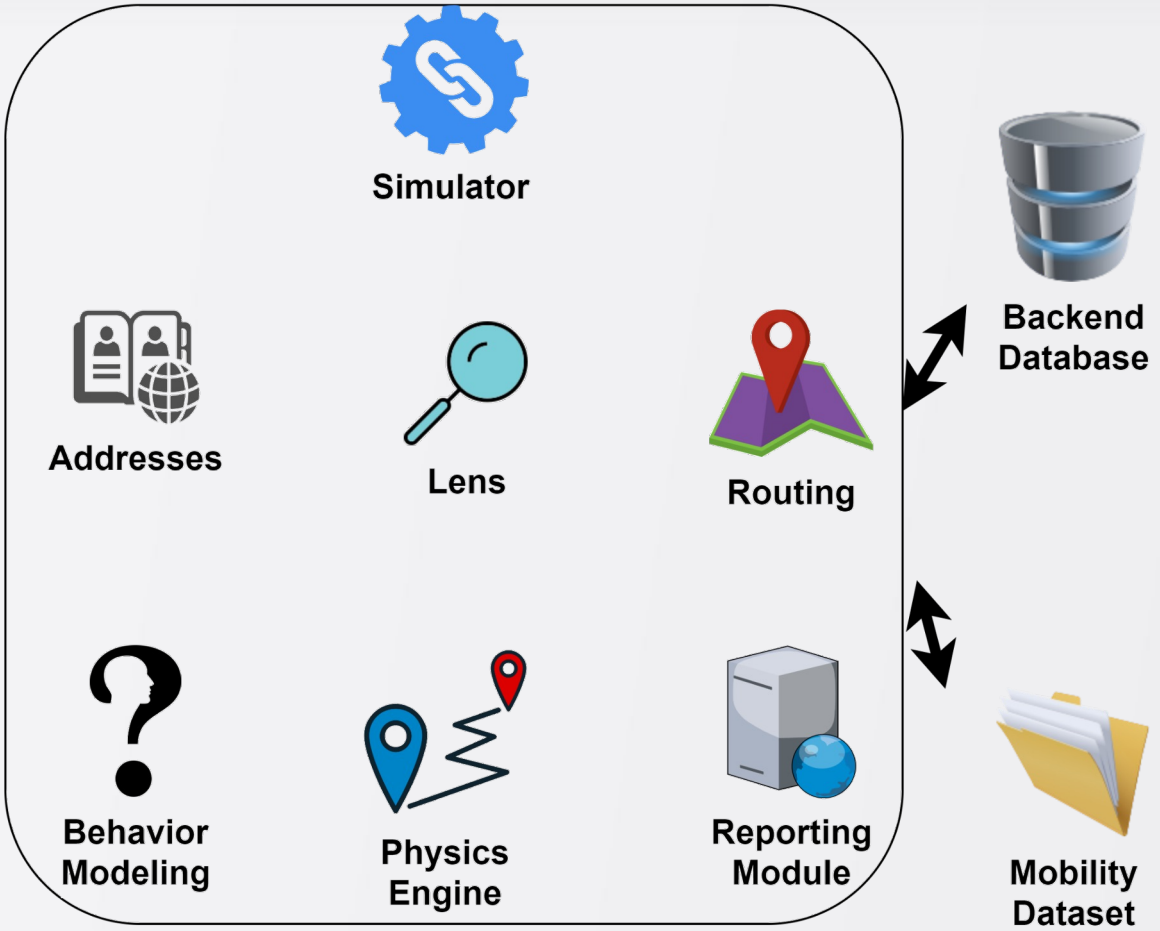
- When should Alice transfer A to Bob?
- When should Bob transfer A to Charlie?
- How the addressing works?
- How the communication works?



Cadence

- Simulator for human movements-based sneakernet.
- Utilizes different routing algorithms to simulate message transferring.
- Allows online visualization of a current simulation.

Cadence


Simulator
Addresses
Lens
Routing
Backend Database
Behavior Modeling
Physics Engine
Reporting Module
Mobility Dataset

Cadence

- **Protocol expressiveness**
  - Simple yet flexible API that enables researchers to concisely specify their routing algorithms.
- **Behavior modeling**
  - Different types of nodes (participants), including potentially malicious actors are simulated.

Cadence

- **Mobility modeling**
  - Simulate messaging in a dynamic network consisting of mobile, human users.
- **Metrics**
  - Collect statistics throughout the simulation and features an interactive reporting module.

Cadence

- **Performance**
  - Operate on computing platforms with varying resources.
  - Golang (strong support of parallelism)
- **Repeatability and scientific validity**
  - Repeatable experiments and deterministic execution.
- **Free, open source software**

Lens

- Easy interface for handling lots of different datasets.

```
type Lens interface {
    Init(logger *logger.Logger)

    Import(path string, dataSetName string) error

    // gets the type of location used for this dataset
    GetLocationType() model.LocationType
}
```

Lens

- Implemented lenses for:
  - Geolife
  - Cabspotting
  - MDC
  - Disasters datasets (partial)

Physics Engine

- Linear movement model
  - Given a node n and two consecutive events $(t_i, \vec{v}_i)$, $(t_j, \vec{v}_j)$;
    - $t_i < t_j$
    - $\vec{v}_x$: location of the node at time t_x
  - Cadence infers the location $\vec{v}_\alpha$ of the node at t_α, where $t_i < t_\alpha < t_j$ as:

$$\vec{v}_\alpha = \vec{v}_i + (t_\alpha - t_i)\frac{|\vec{v}_j - \vec{v}_i|}{t_j - t_i} .$$

Physics Engine

- Defines possible encounters between two nodes:
  - Bounded by a conditions file (JSON)

```
{
  "conditions" : [
    {
      "name" : "distance200m",
      "type" : "distance",
      "params" : {
        "dist" : 200.0
      }
    },
    {
      "name" : "probability25",
      "type" : "probability",
      "params" : {
        "prob" : 0.25
      }
    }
  ]
}
```

Physics Engine

- Defines possible encounters between two nodes:
  - Determines the closest point between any two nodes during a given time period.
  - Checks the conditions for this point. If the conditions are met->encounter.

Routing

- Address versatility:
  - Unicast
  - Geocast
- Routing is controlled by a Logic engine

Logic Engine

- Implement the following interface:

```
type Logic interface {
  Init(log *logger.Logger)

  // stores the initial copy of a message at a node
  PlaceMessage(id model.NodeId, message *Message)

  // callback function for every time a node finds itself in a new position
  // `b` is the marshalled form of the location
  NewPositionCallback(nodeid model.NodeId, t model.LocationType, b []byte)

  // potentially does a message exchange between nodes when an encounter occurs.
  HandleEncounter(encounter *model.Encounter,
       messageDBChan chan *model.MessageDB,
       receivedmessageDBChan chan *model.DeliveredMessageDB) float32

  // ... supporting routines omitted for brevity ...
}
```

Logic Engine

- **PlaceMessage** - Bootstraps messaging by specifying the origination of a message.
- **NewPositionCallback** is called whenever a node is in a new position.
  - Useful for simulating certain protocols (e.g., Aviv et al.'s HumaNets protocol).
- **HandleEncounter** governs how an encounter should be handled.

Logic Engine (Flooding)

PlaceMessage: put a message in a node's queue.

NewPositionCallback: do nothing

HandleEncounter:

Logic Engine

- **General factors**
  - Distance
  - Probability of an Encounter (global or per message)
  - Connection Duration
- **Device factors**
  - Battery Consumption
  - Memory Usage

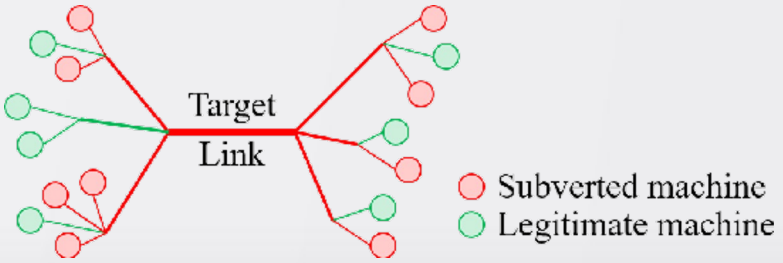
Behavior Modeling

- Attacker nodes
  - Flooder
  - Dropper

```
1  type Attacker interface {
2    Init(log *logger.Logger)
3
4    // runs an attack of the attacker node, using its queue of messages,
5    // during an encounter
6    Attack(encounter *model.Encounter, attacker model.NodeId,
7       attackerMap *sync.Map)
8
9    // ... supporting routines omitted for brevity ...
10 }
```

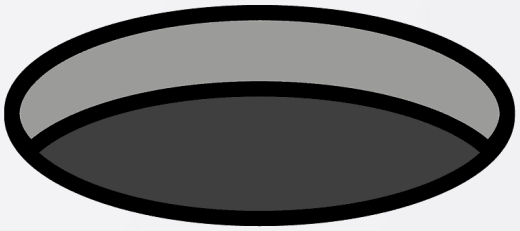
Behavior Modeling

- **Flooder**
  - Injects spurious messages whenever it meets a new node.
  - A sufficiently large flooder population can create a version of the *Coremelt attack*.



Behavior Modeling

- **Dropper**
  - Does not pass any message to any node and instead drops every message it receives.
  - Creates a typical DOS attack.



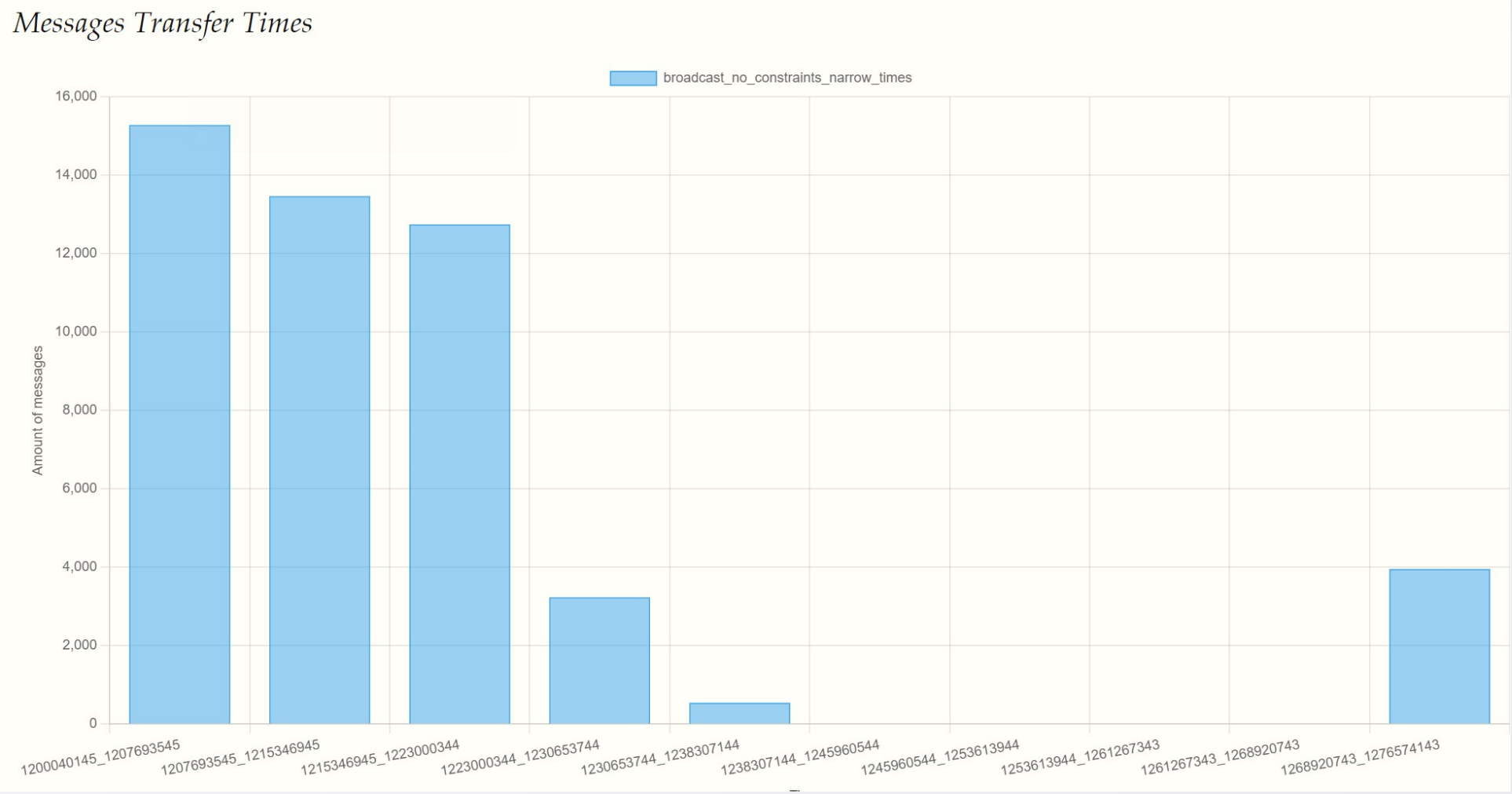
Reporting Module

- A web service
- Allows researchers to run various reports and plot.
- Currently supported reports include plots of delivery rates, contact rates, and node lifetimes.

Reporting Module

- Adding a new report requires registering a unique URL (e.g., “/avg-throughput”) and an event handler.
- Formatting reports is accomplished through Golang’s built-in HTML template language.

Reporting Module



Future Work

- Optimization
  - Running dense datasets require enormous computational resources
    - Moving to Encounter-based simulator instead of events based.
  - Relational DB backend (i.e., MySQL)
    - Moving to memory-backed data stores (e.g., Redis).

Future Work

- Protocols
  - New routing protocols
  - Currently, the simulator supports only a single configuration per execution.
    - Different protocols in parallel, ”parallel worlds”.
- Documentation of new routing protocols and node behaviours.

Summary

- Cadence is a simulator for human movement-based communication.
- It supports different datasets, routing algorithms, addresses and node behaviors.
- Cadence is an ongoing project, and will be extended in the future.

Availability

- Cadence is available as free and open-source software and can be downloaded from https://github.com/GUSecLab/cadence.

Acknowledgments

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Any Questions?