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Swiss Federal Institute of Technology Zurich

# Gadara: Dynamic Deadlock Avoidance for Multithreaded Programs

Speaker: Martin Lanter

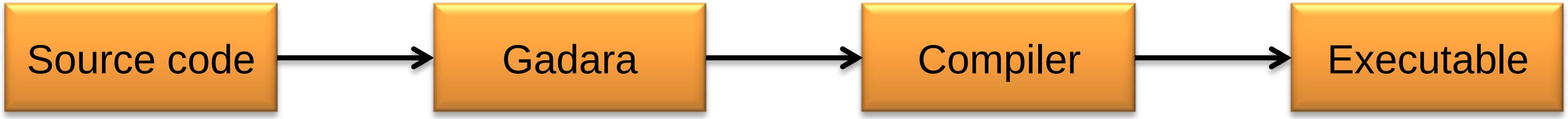
# Deadlock

- Circular-mutex-wait deadlocks in conventional shared-memory multithreaded programs.

| Thread 1 | Thread 2 |
| --- | --- |
| acquire lock 1 | acquire lock 2 |
| … | … |
| acquire lock 2 | acquire lock 1 |
| … | … |
| release locks | release locks |

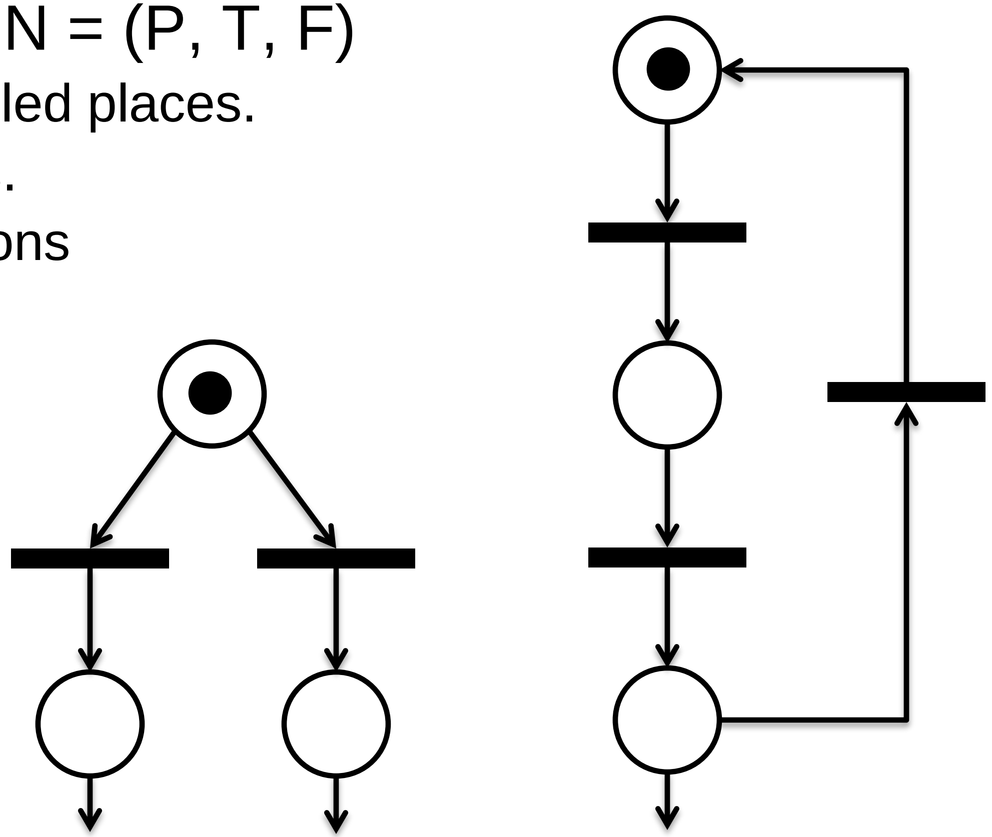
# Gadara

- Intelligently postpones lock acquisition attempts
- All circular-mutex-wait deadlocks are eliminated
- No new deadlocks or other liveness or progress bugs
- No global reasoning necessary for the programmer

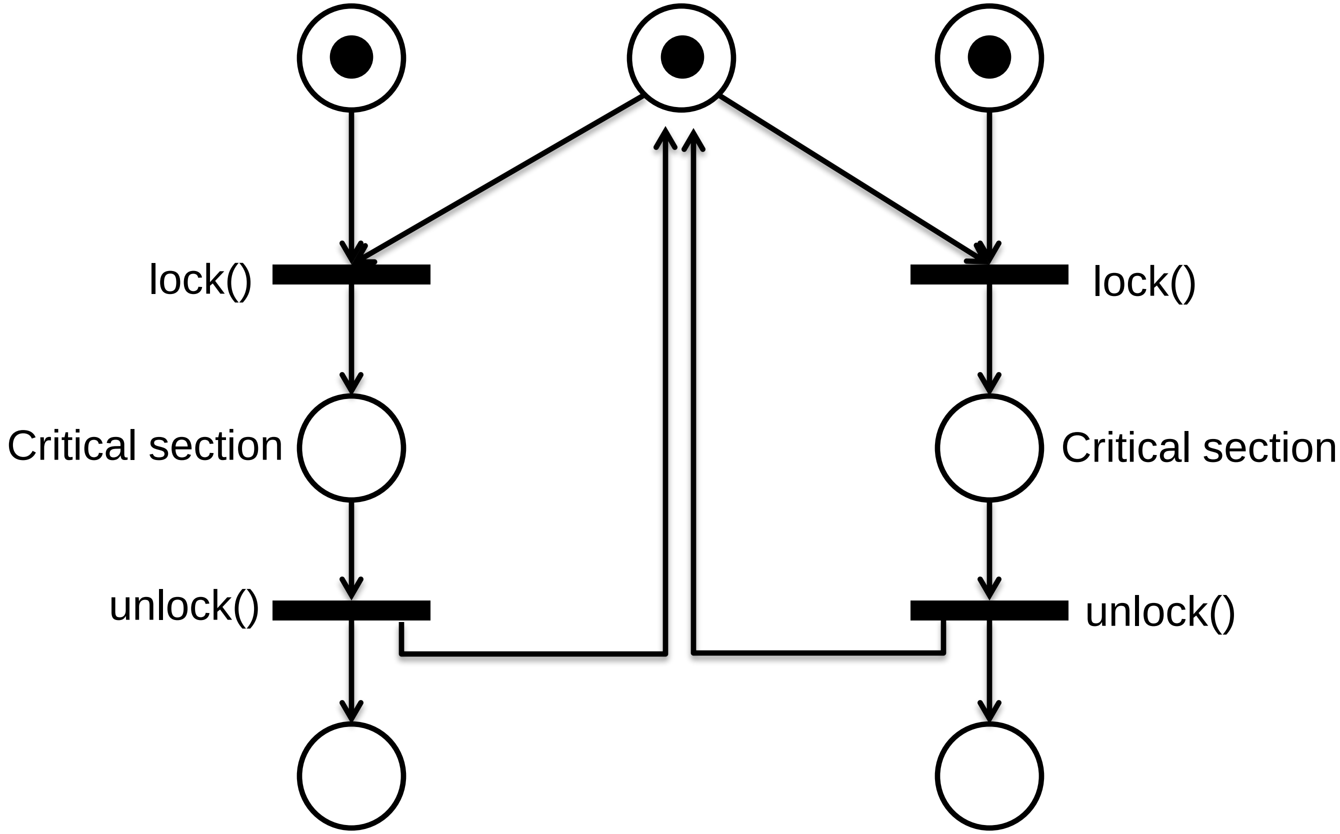


# Petri nets

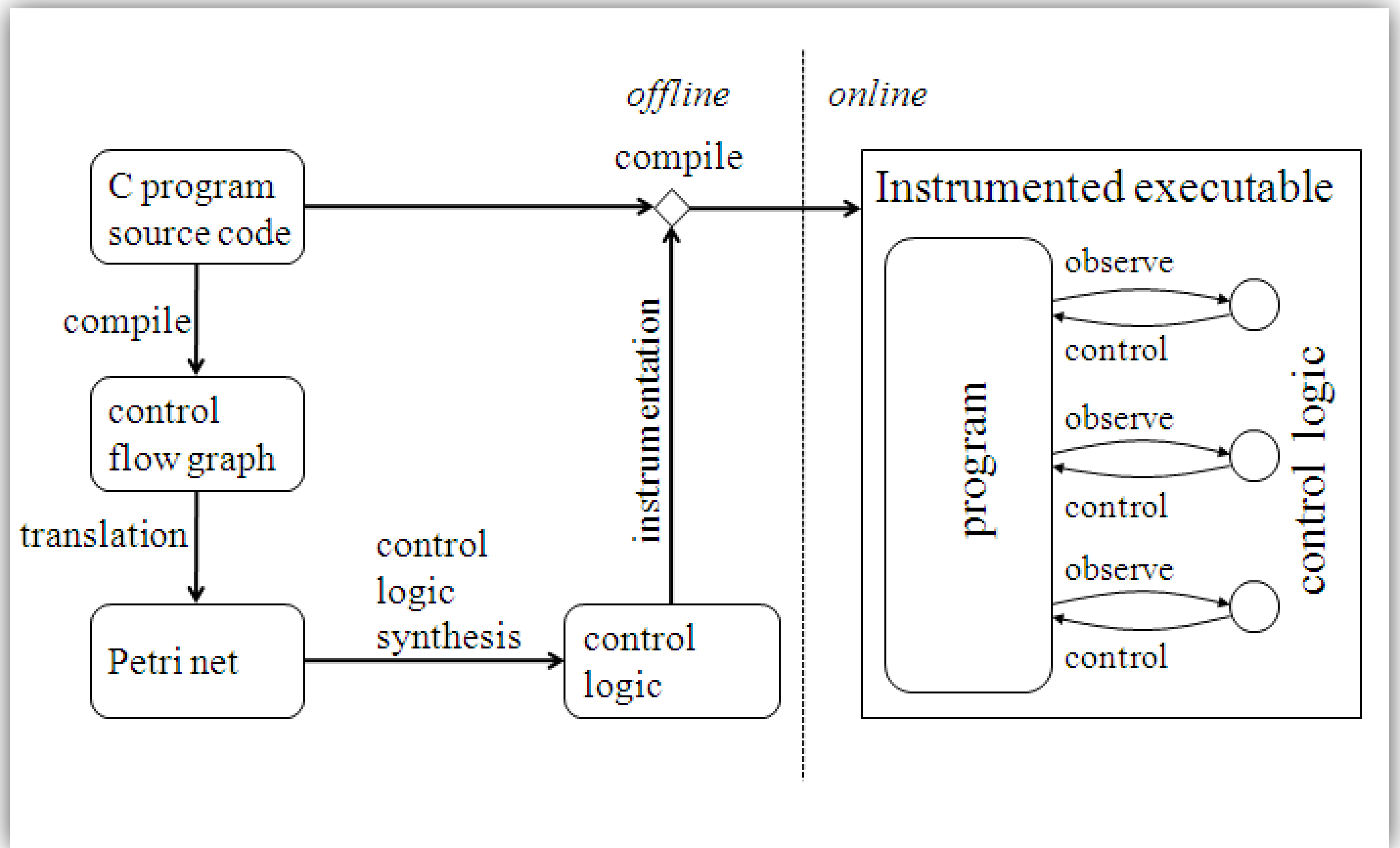
- A Petri net is a triple N = (P, T, F)
  - P is a set of states, called places.
  - T is a set of transitions.
  - F is a set of flow relations



# Lock for critical sections



# Gadara Architecture

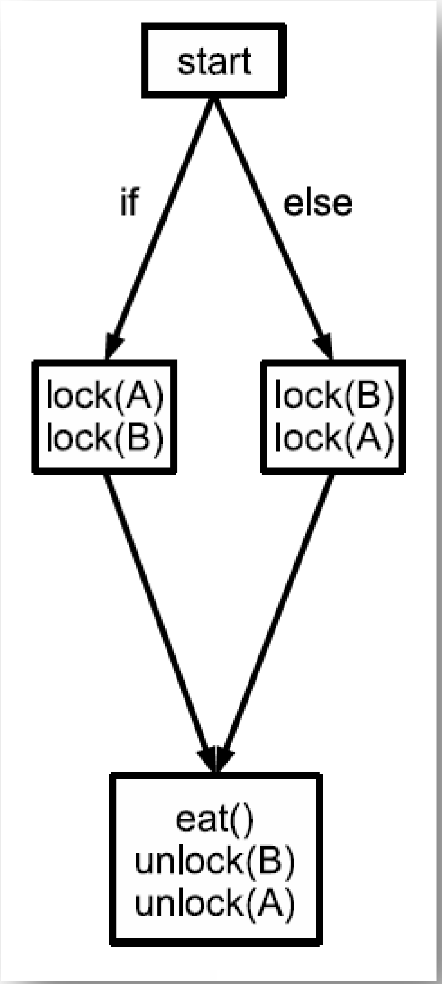


# Philosopher

```
void * philosopher(void *arg) {
    ...
    if (random()>0.5) {
        /* grab A first */
        pthread_mutex_lock(&forkA);
        pthread_mutex_lock(&forkB);
    } else {
        /* grab B first */
        pthread_mutex_lock(&forkB);
        pthread_mutex_lock(&forkA);
    }
    eat();
    pthread_mutex_unlock(&forkA);
    pthread_mutex_unlock(&forkB);
    ...
}
```

http://gadara.eecs.umich.edu/papers/UMGS10_poster.pdf

# Philosopher

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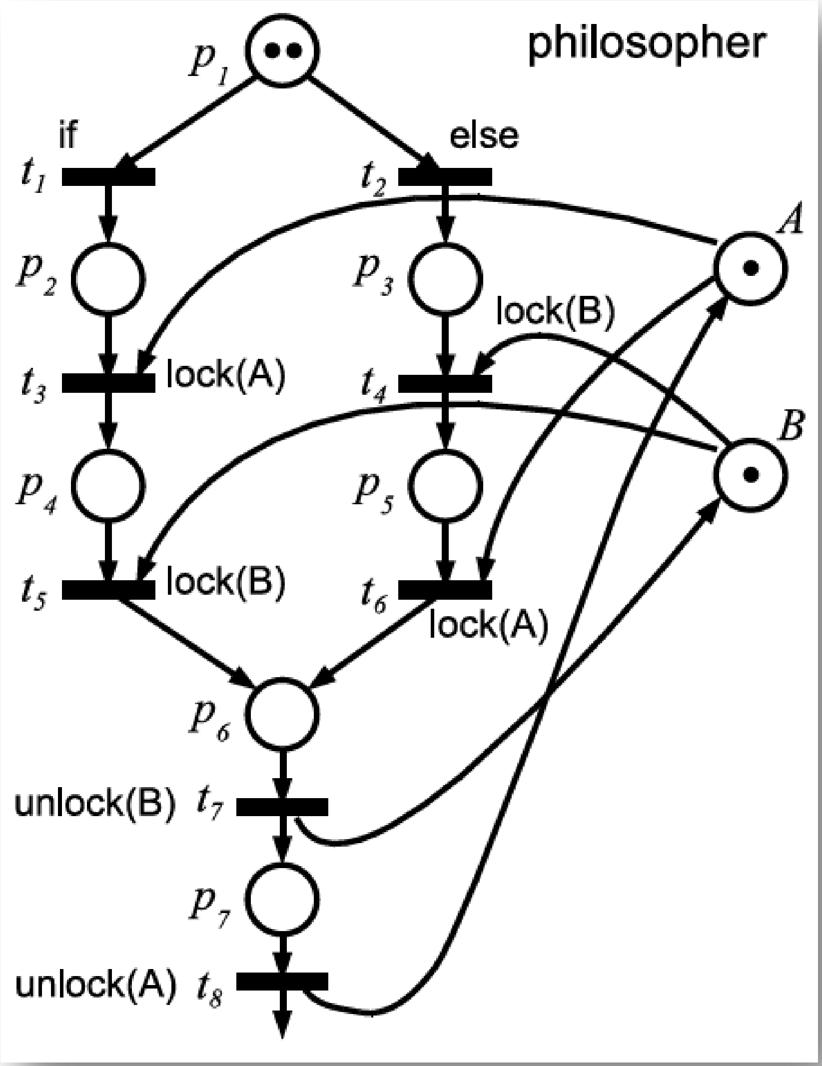


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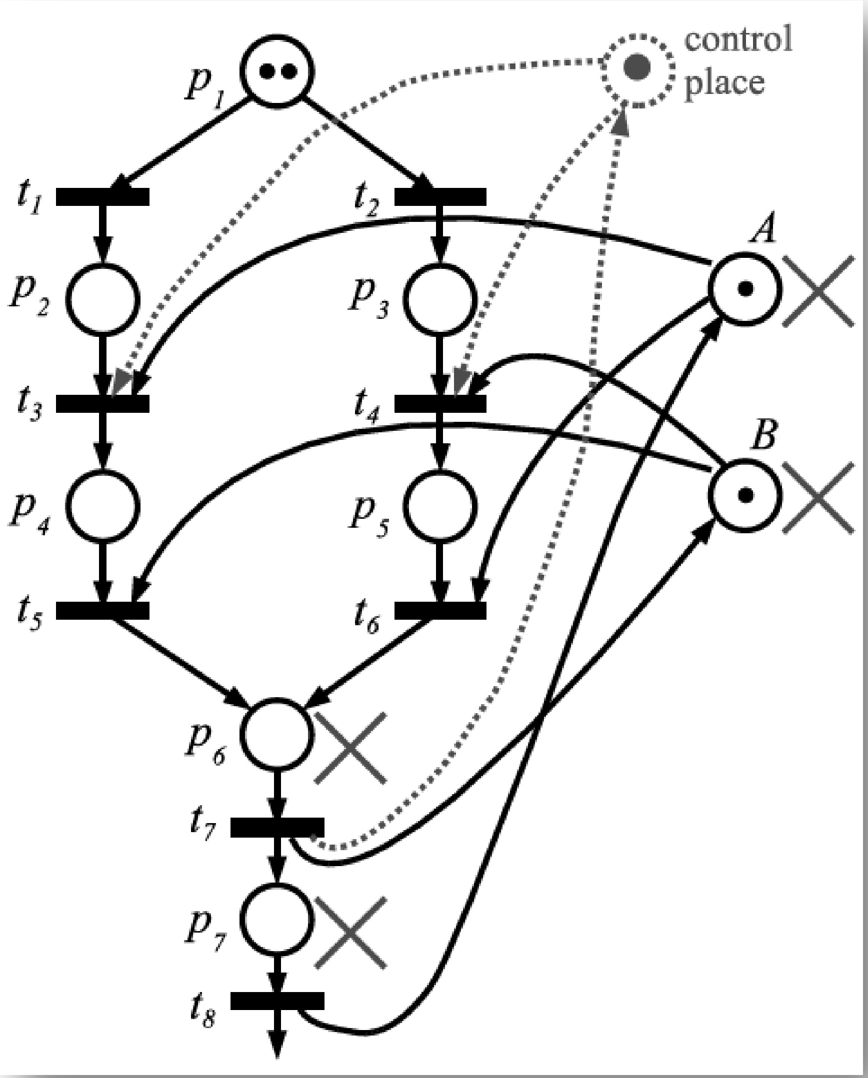
# Philosopher

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# Philosopher

```
void * philosopher(void *arg) {
        …
        if (random()>0.5) {
                /* grab A first */
                gadara_lock(&forkA, &ctrlplace);
                pthread_mutex_lock(&forkB);
        } else {
                /* grab B first */
                gadara_lock(&forkB, &ctrlplace);
                pthread_mutex_lock(&forkA);
        }
        eat();
        gadara_replenish(&ctrlplace);
        pthread_mutex_unlock(&forkA);
        pthread_mutex_unlock(&forkB);
        …
}
```

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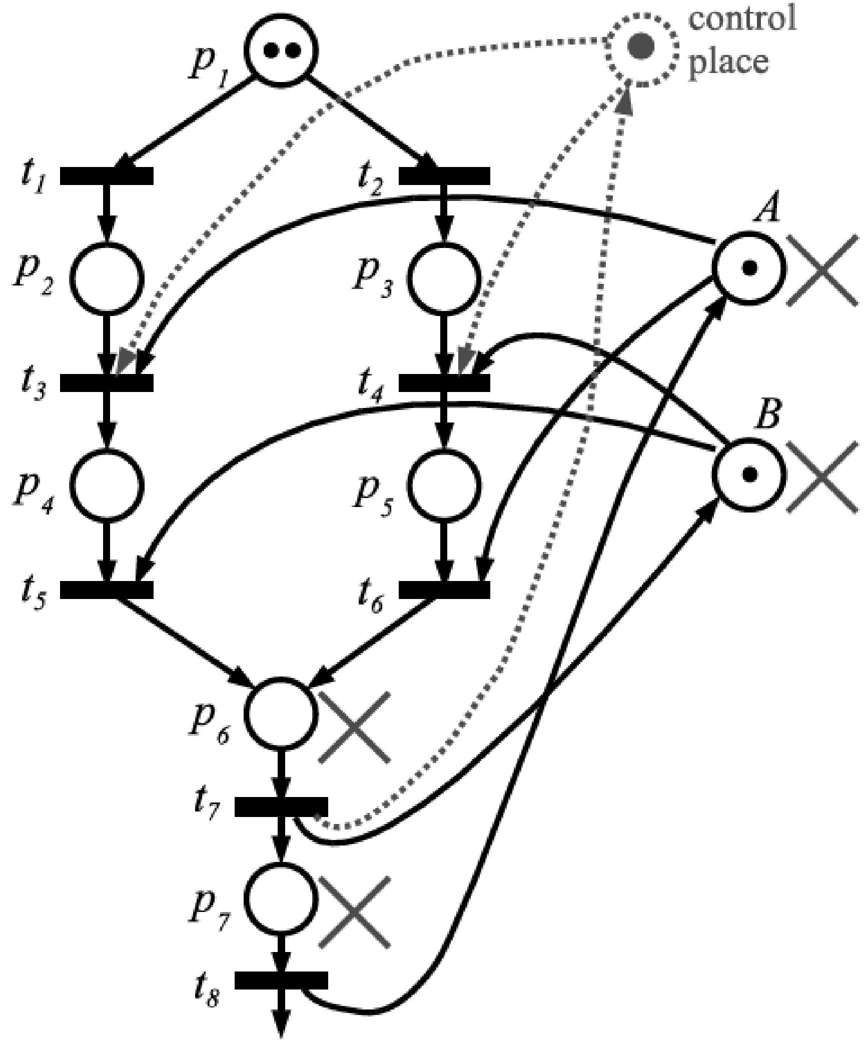
# Siphon

- Set of places that never regains a token if it becomes empty



# Control logic synthesis

- Siphon
  - Set of places that never regains a token if it becomes empty

- Supervision Based on Place Invariants technique (SBPI)
  - Solves a system of inequalities

- Insert control places that encode feedback control logic

- Apply SBPI repeatedly to fix newly created siphons

# Gadara control logic

- Provably Deadlock free
- Maximally permissive
  - With respect to the program model
- Decentralized
- Fine-grained
- Highly concurrent

- Conservative
  - Needs annotations

# Limitations

- Limits inherent to the problem domain
  - Inevitable deadlocks
  - E.g. repeatedly locking a nonrecursive mutex

```
if (cond) {
      lock(L)

…

if (cond) {
      unlock(L)
```

- Artifacts of the current prototype
  - False paths problem

```
while (…)
      lock(&(a[i]));
```

- Only Pthread functions
  - Homebrew synchronization primitives must be annotated

```
lock(&S->M);
…
free(&S);
```

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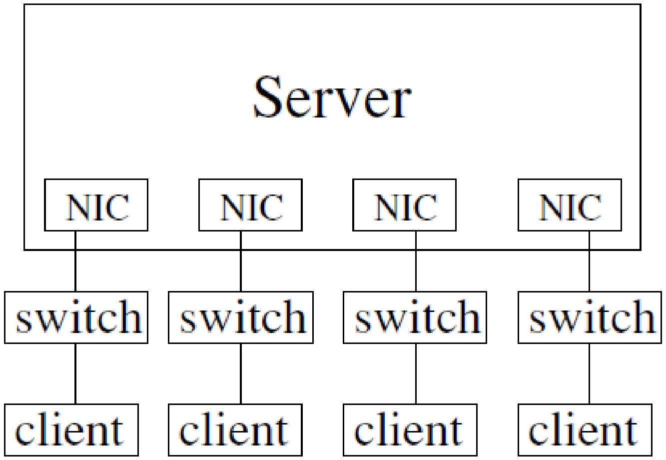
# Benchmark

- C/Pthread client-server publish-subscribe application
  - subscribe to a channel
  - publish data to a channel
  - request a snapshot of all of their current subscriptions

- 12 worker threads
- 4 x 1024 clients



# Benchmark Results

| | Heavy Load<br>Throughput (Mbit/s) | Light Load<br>Resp. Time (ms) |
|---|---|---|
| DL free | 94.25 | 10.83 |
| Gadarized | 76.88 | 10.52 |
| STM | 47.15 | 66.70 |

# Gadara Performance

- Runtime performance overhead < 18%
  - Typically negligible

- Compile time overhead tolerable
  - Not worse than build time

# Credits

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(EECS Department, University of Michigan)

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(Hewlett-Packard Laboratories)