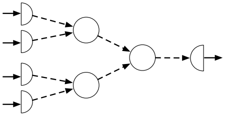
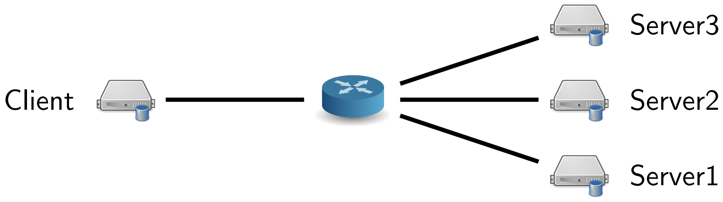
FLICK: Developing and Running Application-Specific Network Services



Presenter: Richard G. Clegg, Imperial College
Imperial College: Abdul Alim, Luo Mai, Lukas Rupprecht, Eric Seckler, Paolo Costa, Peter Pietzuch, Alexander L. Wolf
Cambridge: Nik Sultana, Jon Crowcroft, Anil Madhavapeddy, Andrew W. Moore, Richard Mortier
Nottingham: Masoud Koleini, Carlos Oviedo, Derek McAuley
Kent: Matteo Migliavacca

Packet processing vs application-specific middlebox



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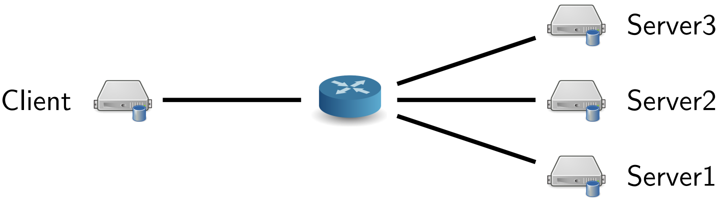

Packet processing
(ECMP loadbalancer)

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process(packet):
  dest=hash(packet.srcIP + packet
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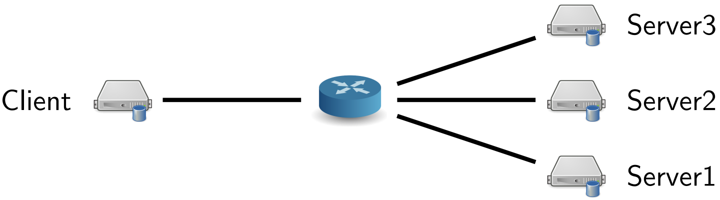
  forward(packet,dest);
```

Packet processing vs application-specific middlebox



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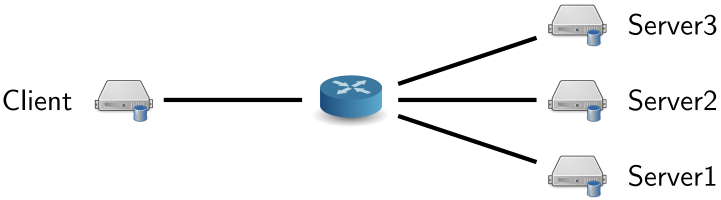

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Application-specific
(memcached router)

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process(key_val_pair):
  dest=hash(key_val_pair.key);
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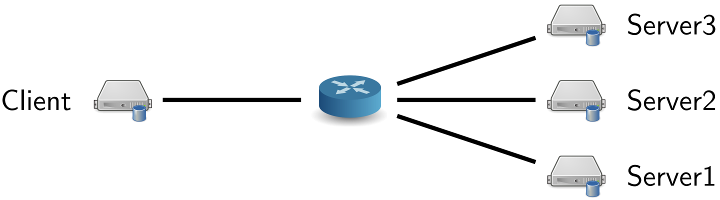

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Application-specific
(memcached router)

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process(key_val_pair):
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```
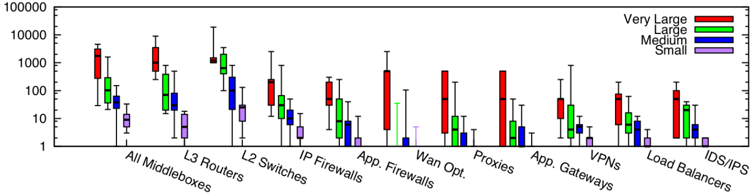

- Applications have different data formats (e.g. key-value pairs, HTTP request/reply).
- TCP flow not packets.
- One packet != one data item.

Problem: The application-specific middlebox



Figures from: Making Middleboxes Someone Elses Problem, Sherry et al. SIGCOMM 2012

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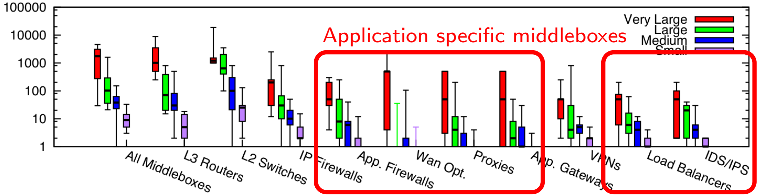

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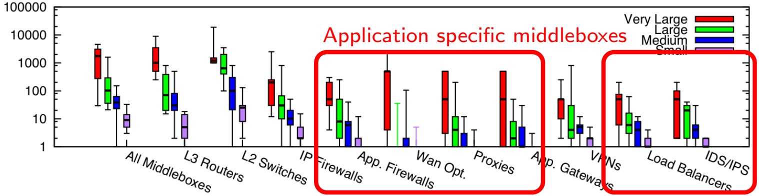

NetAgg: Using Middleboxes for On-path Aggregation
CoNEXT 2014

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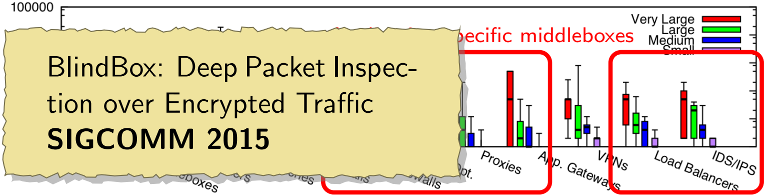

BlindBox: Deep Packet Inspection over Encrypted Traffic
SIGCOMM 2015

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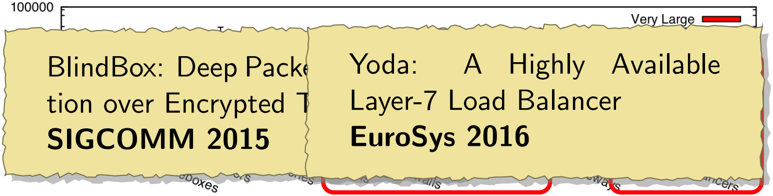

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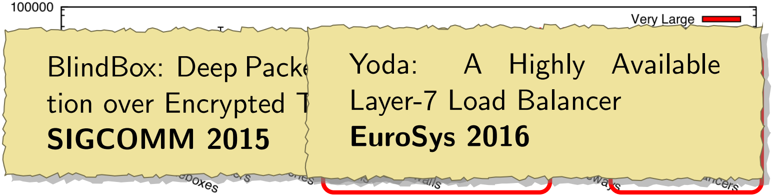

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Introducing mcrouter:
A memcached protocol router
Facebook blog

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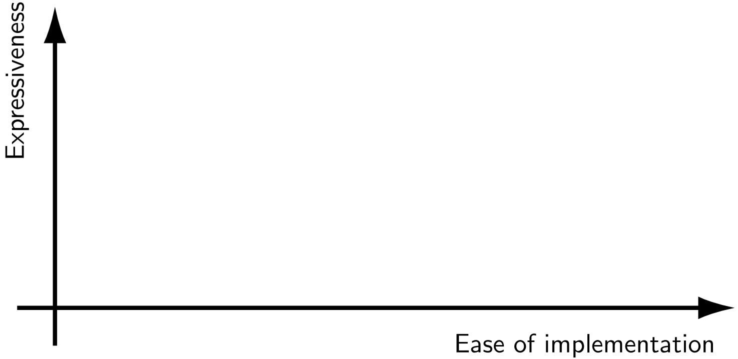
Creating new application-specific middlebox



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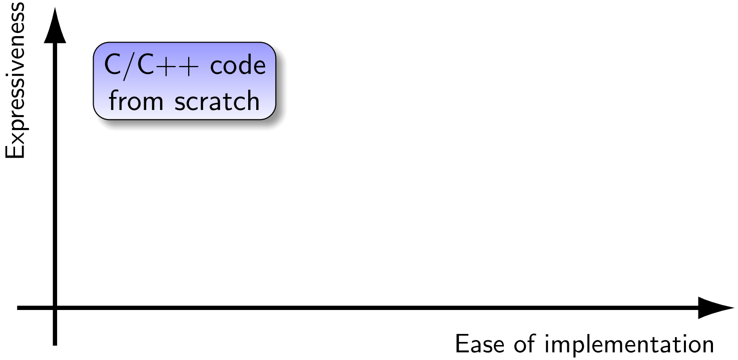

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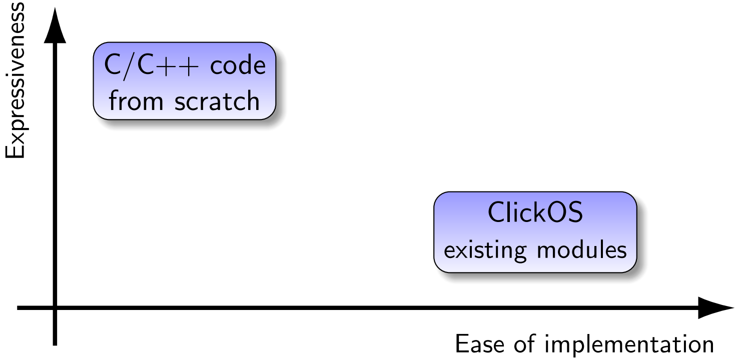

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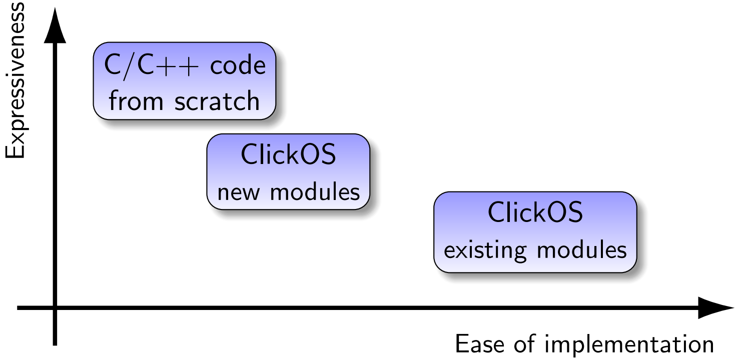

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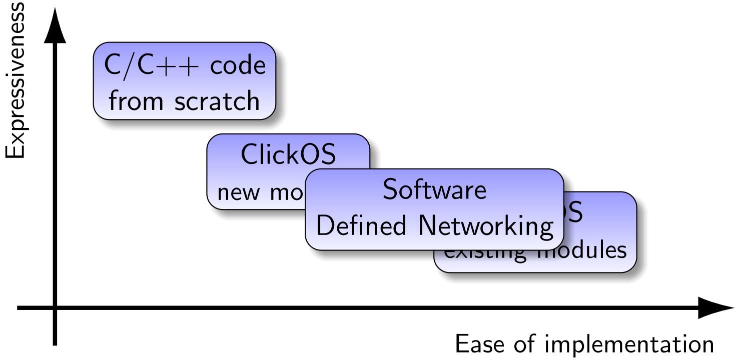
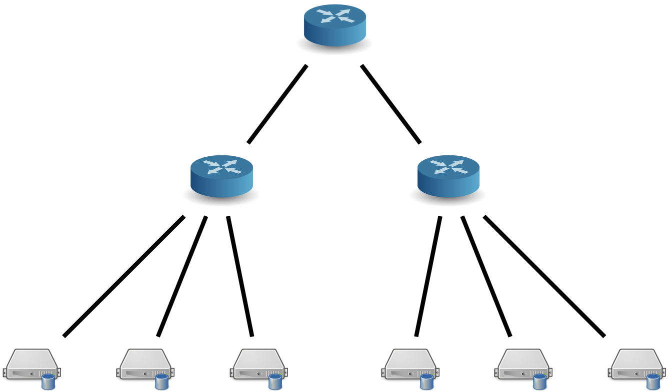


FLICK for the datacentre



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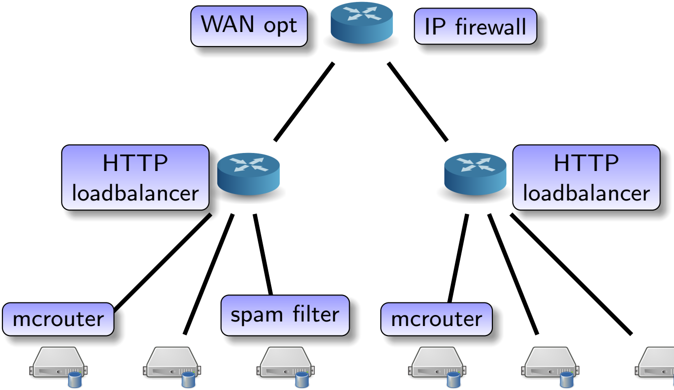

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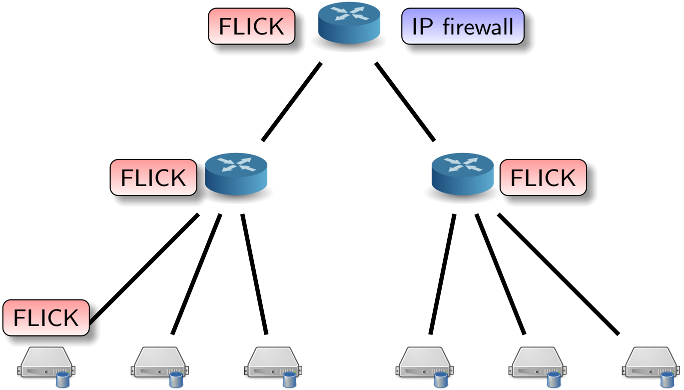

General system for application-specific middleboxes?

Challenge 1: Ease-of-use

Rapidly express many middlebox functions.
System created in hours not weeks/months.

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Generality must not have large performance penalty.
Performance similar to specially written system.

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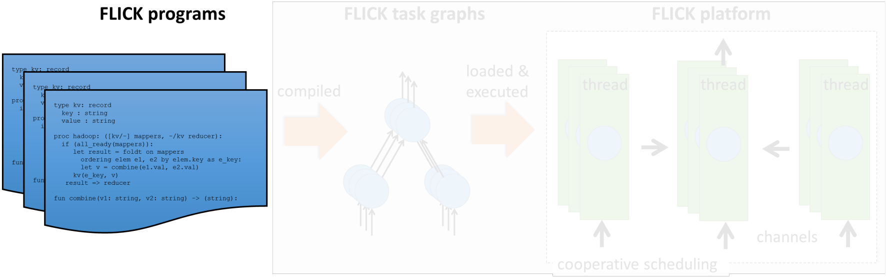
Challenge 2: Performance

Generality must not have large performance penalty.
Performance similar to specially written system.

Challenge 3: Safety/Isolation

Middleboxes should be "safe" in resource usage.
Applications on same machine share resources well.

FLICK overview

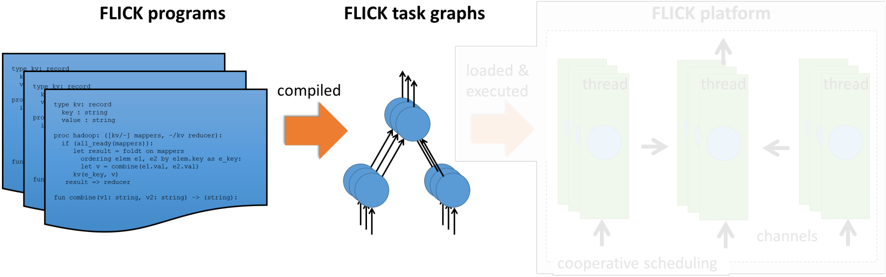


Flick programs

Domain specific language (DSL) for application-specific middleboxes.

Tens of lines of code not tens of thousands

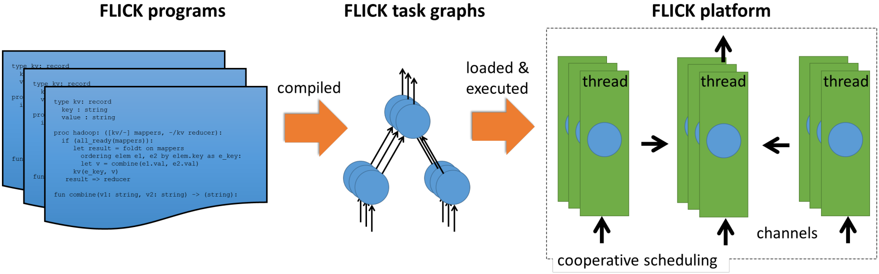
FLICK overview



Flick task graphs

Break work into independently schedulable units (tasks).
Join tasks by channels into task graphs.

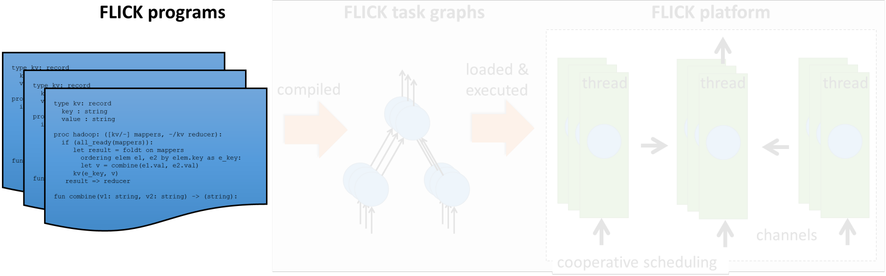
FLICK overview



Flick platform

The running implementation. Integrates the compiled C++ from DSL. Handles network connections, worker threads and scheduling tasks.

FLICK – the language



FLICK (language) – features

```
type cmd: record
 key    : string

proc Memcached: (cmd/cmd client, [cmd/cmd] backends)
  | backends => client
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fun target_backend: ([-/cmd] backends, req:cmd) -> ()
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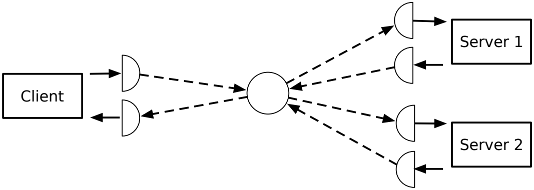
- Process as basic unit of code expresses flow of typed data.
- Control structures restricted. Bounded loops and hence execution time.
- Strongly typed for safety.

FLICK (language) – processing data (memcached)

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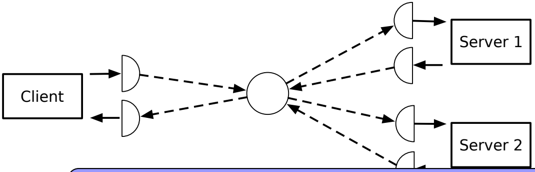

Structure allows work to
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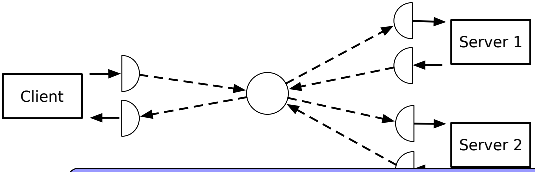

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Convenient abstractions for middlebox

```
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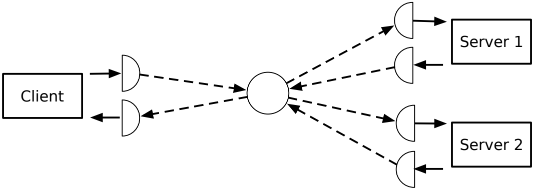

Type definition only necessary fields included

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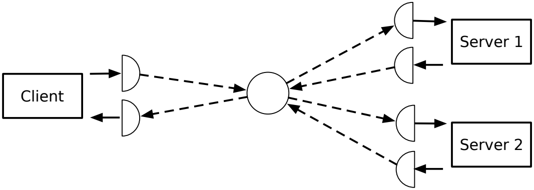

Process: entry point defines how channels connect

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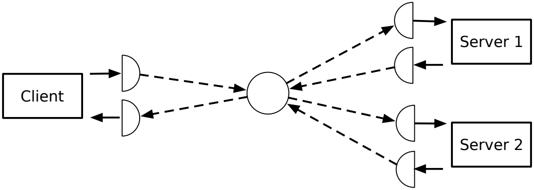

Function selects backend using key

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FLICK (language) – parsing data (memcached)

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type cmd = unit {
    %byteorder = big;
    magic_code           : uint8;
    opcode               : uint8;
    key_len              : uint16;
    extras_len           : uint8;
                         : uint8;  # anon field - future use
    status_or_v_bucket : uint16;
    total_len            : uint32;
    opaque               : uint32;
    cas                  : uint64;
    extras    : bytes &length = self.extras_len;
    key       : string &length = self.key_len;
    value     : bytes &length = self.value_len;
};
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Based on Spicy/binpac++ [IMC2006]

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Developer can quickly parse even complex formats like HTTP

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Based on Spicy/binpac++ [IMC2006]

Developer can quickly parse even complex formats like HTTP

Compiles to efficient C++. Only extracts fields used in processing

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Fixed width field easy to define

FLICK (language) – parsing data (memcached)

Field length depends on previous field

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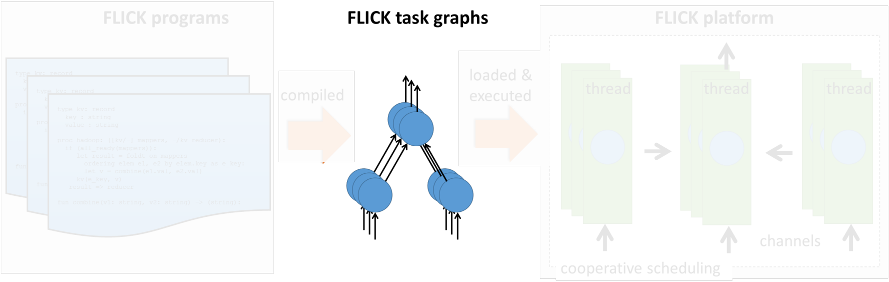
FLICK – the task graph



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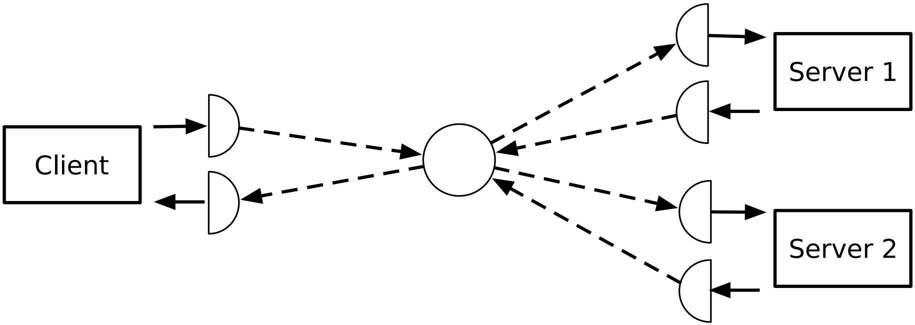
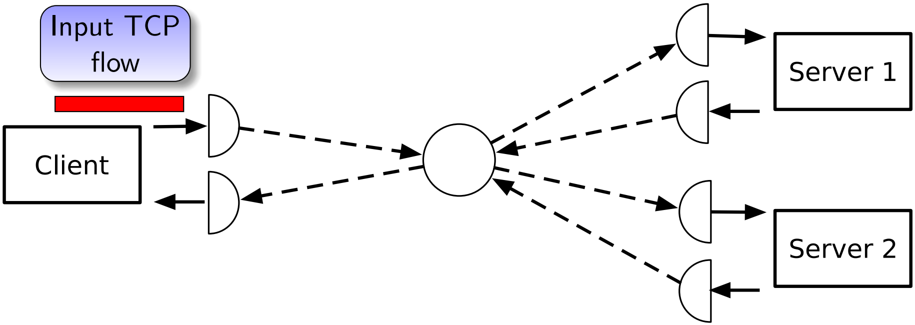
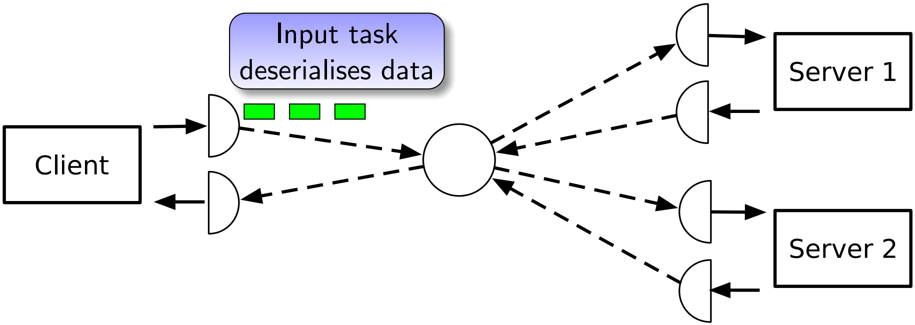


Separate input, processing and
output tasks enable parallelism

FLICK – the task graph



FLICK – the task graph



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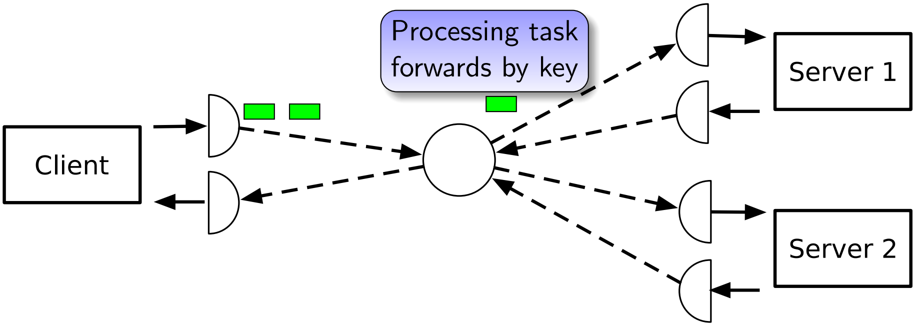

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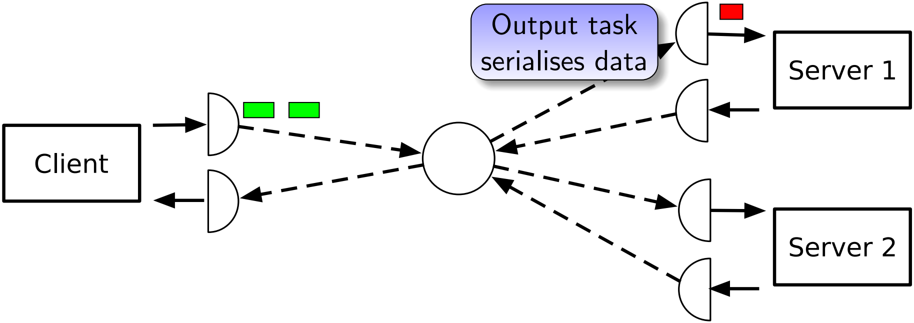

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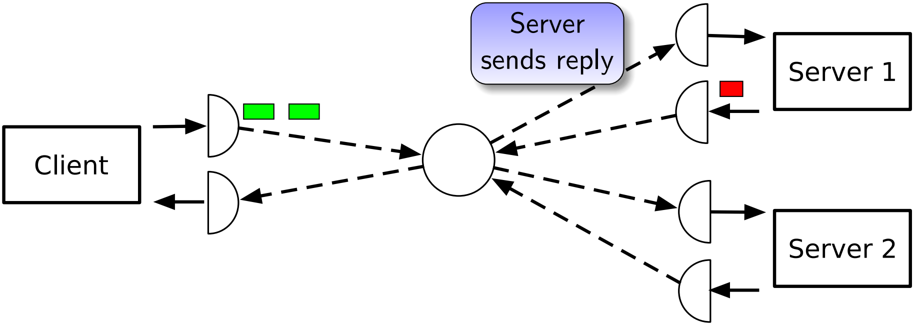

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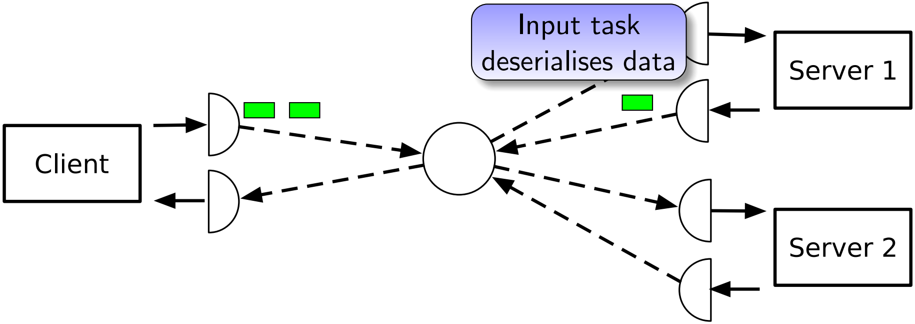

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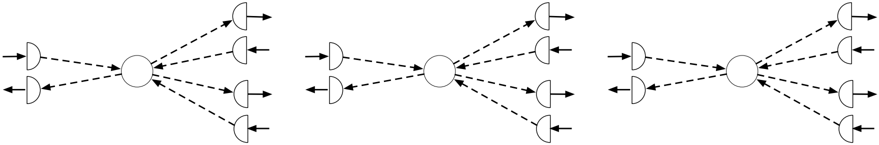

- For memcached router each client has its own task graph.

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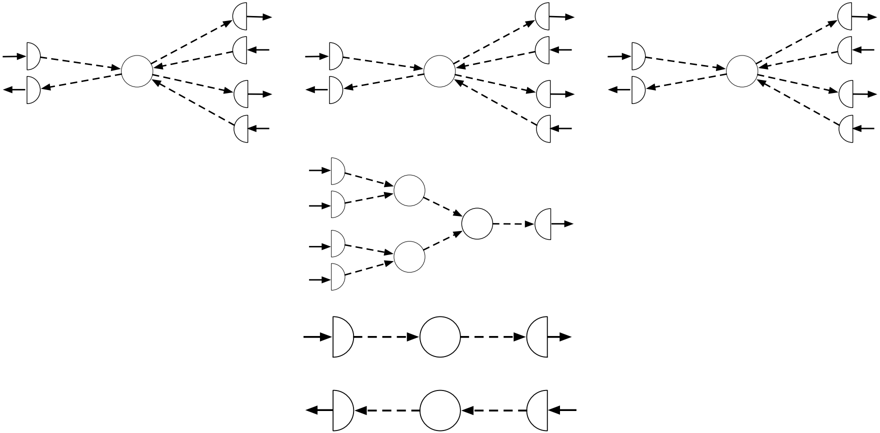
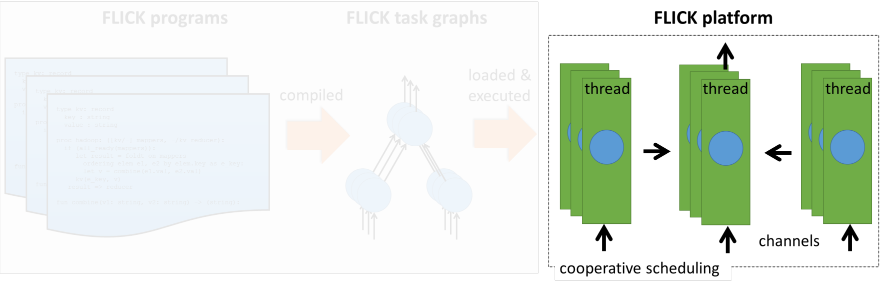


- For memcached router each client has its own task graph.
- Different types of task graph – some have data parallelism.
- Data and task parallelism.

FLICK – the platform



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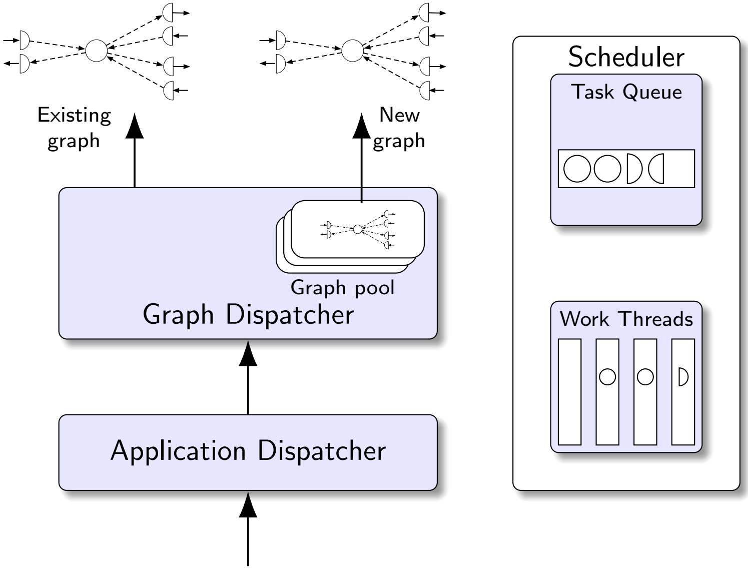
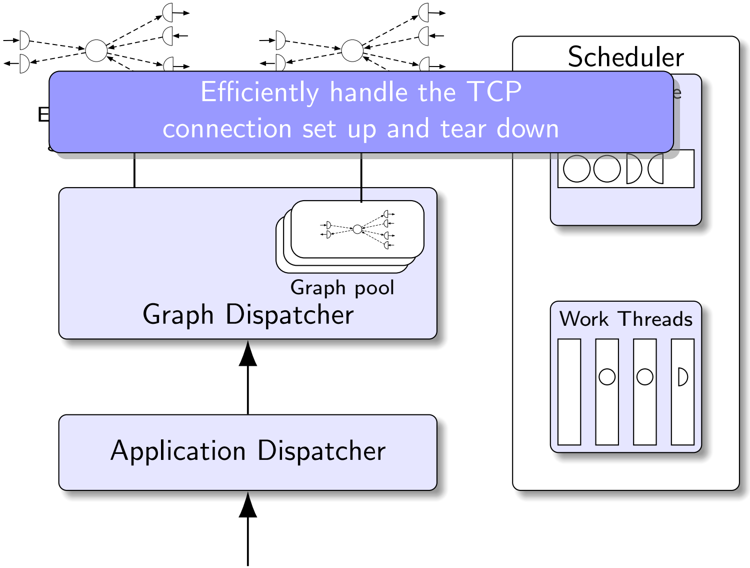


FLICK – the platform



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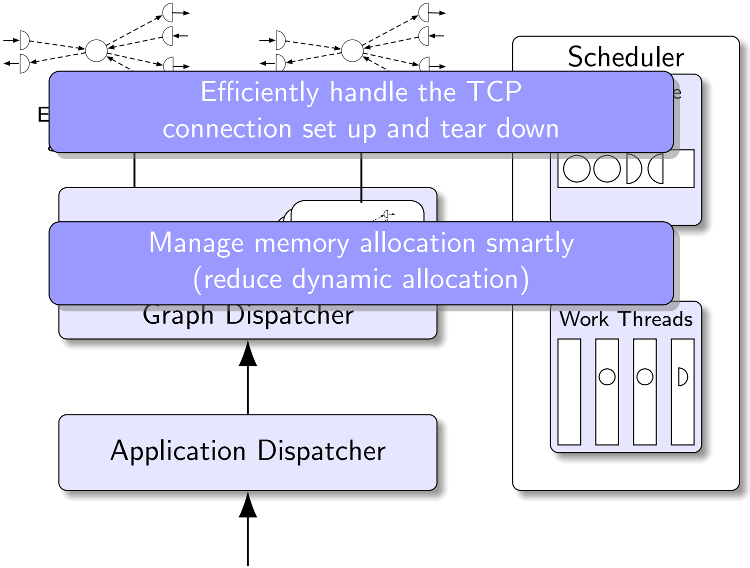

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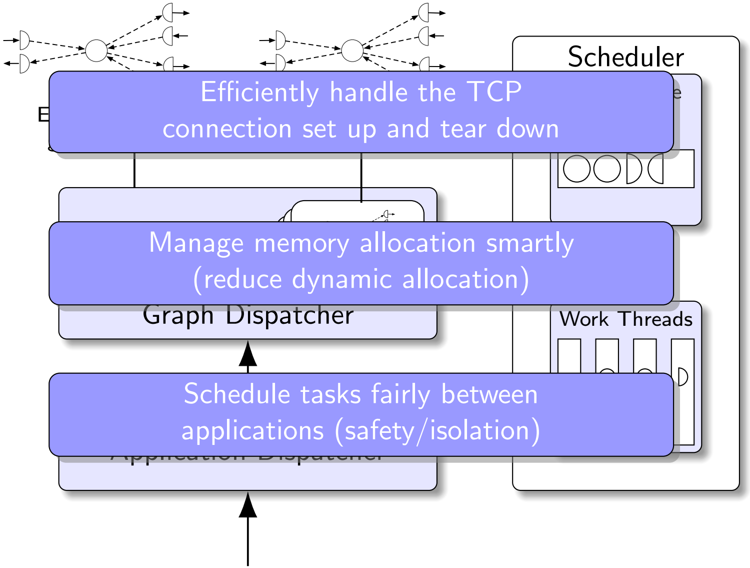
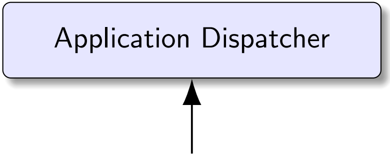


Efficiently handle the TCP connection set up and tear down

Manage memory allocation smartly (reduce dynamic allocation)

Schedule tasks fairly between applications (safety/isolation)

FLICK – the platform



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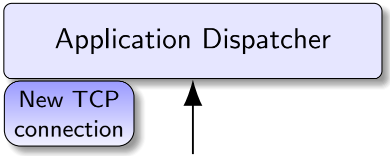

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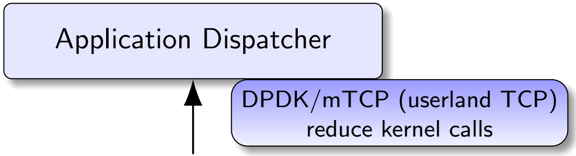

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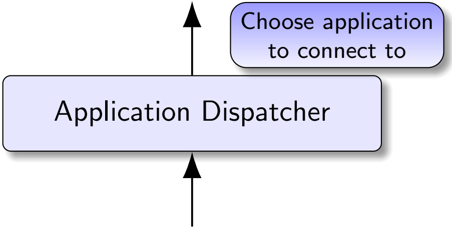

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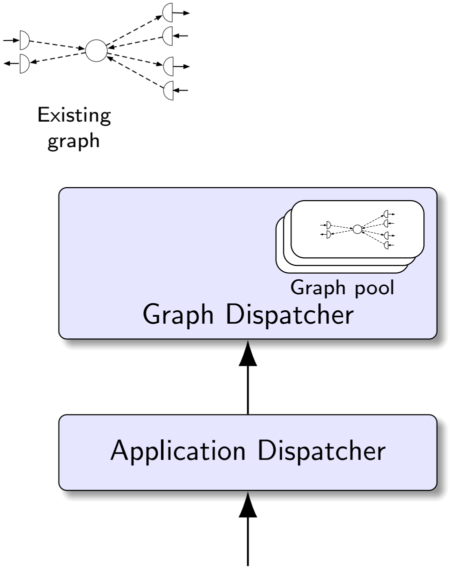

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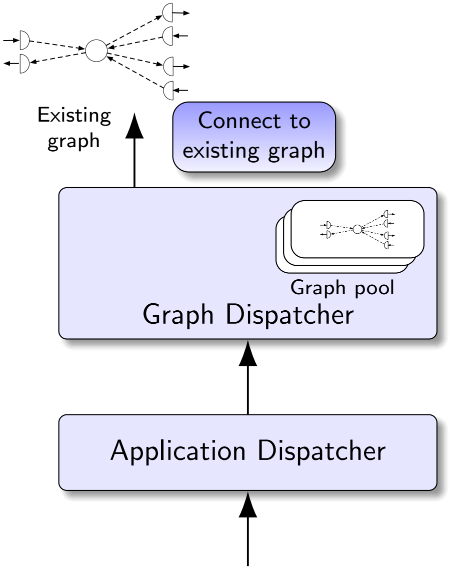

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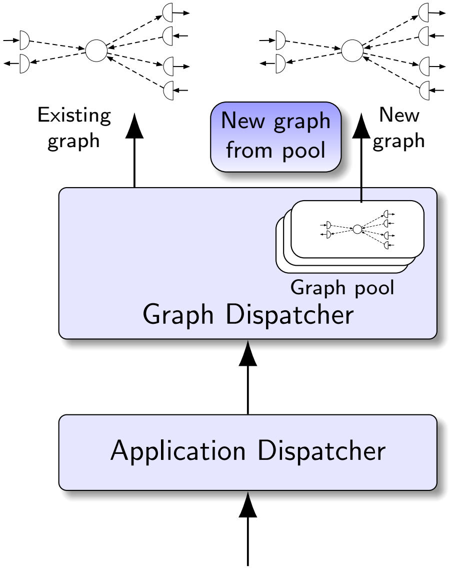
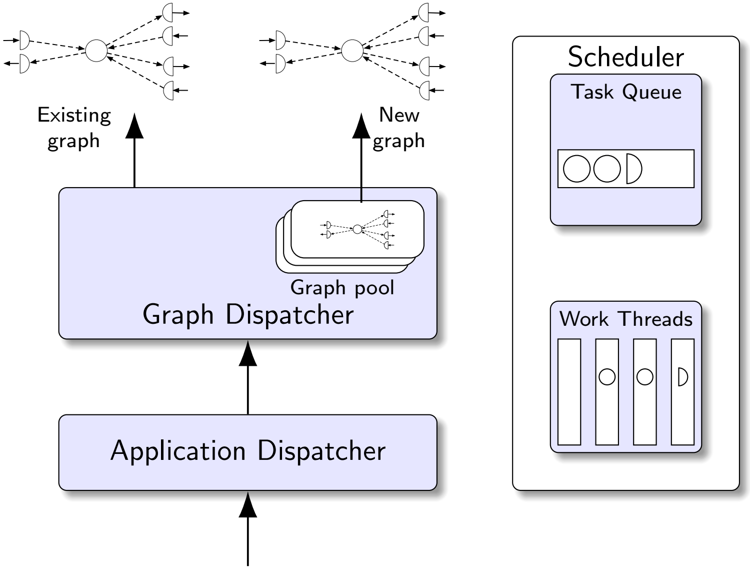


FLICK – the platform



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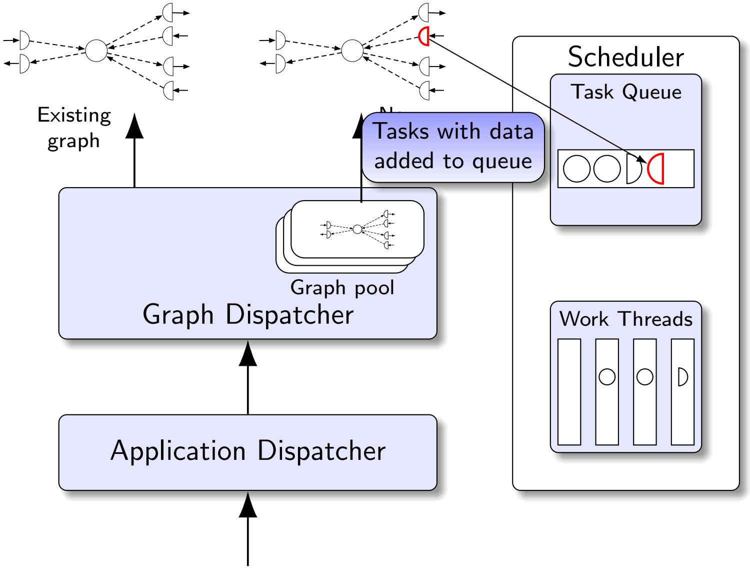

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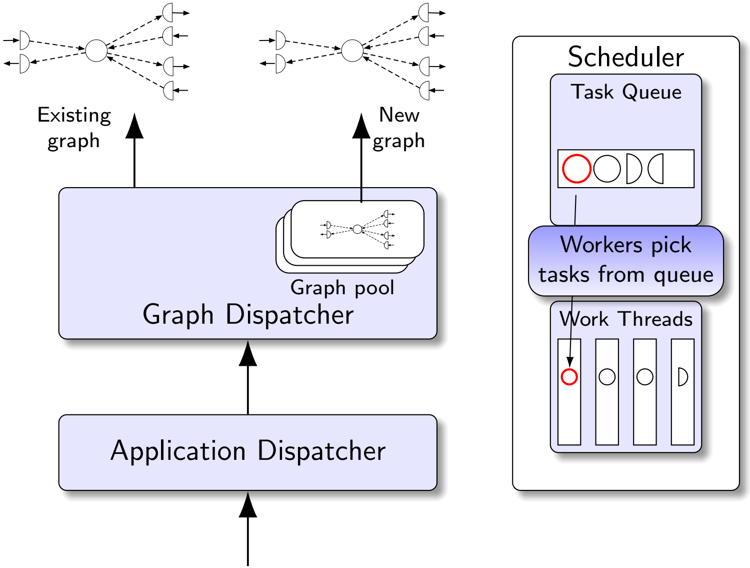

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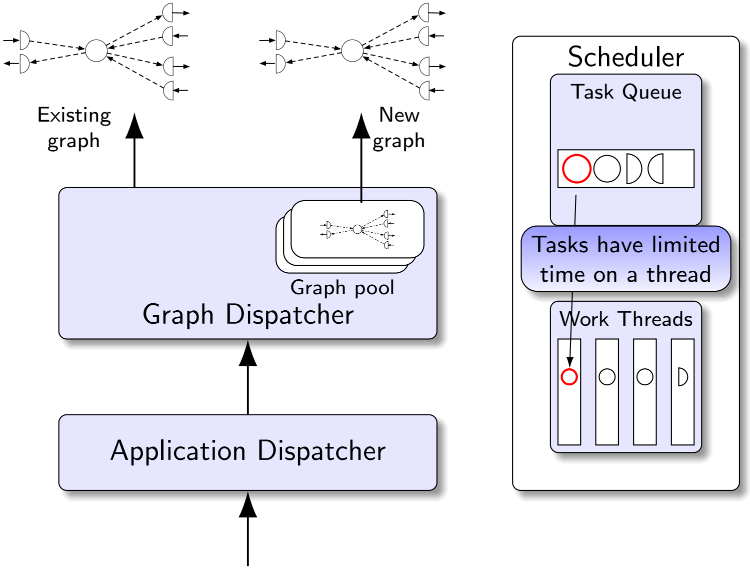

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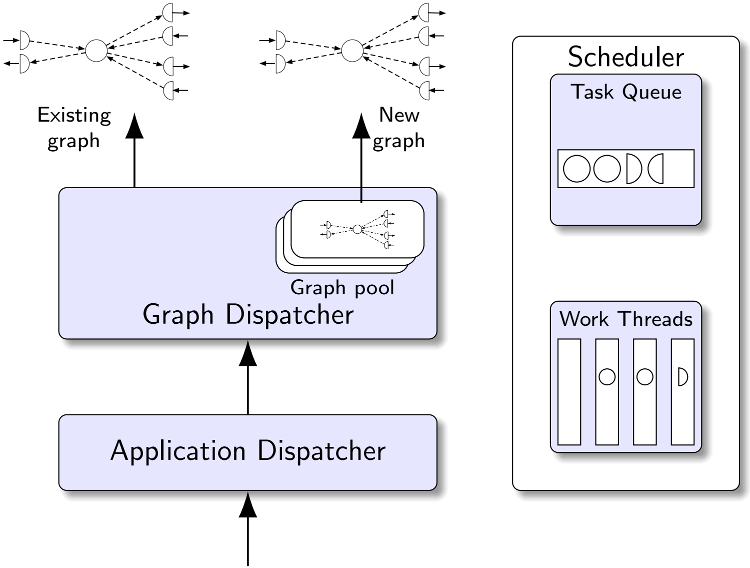
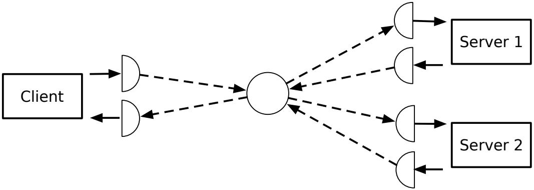


Evaluation – latency/throughput (loadbalancer)



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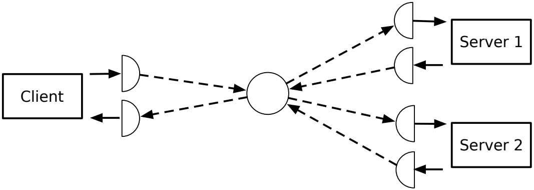
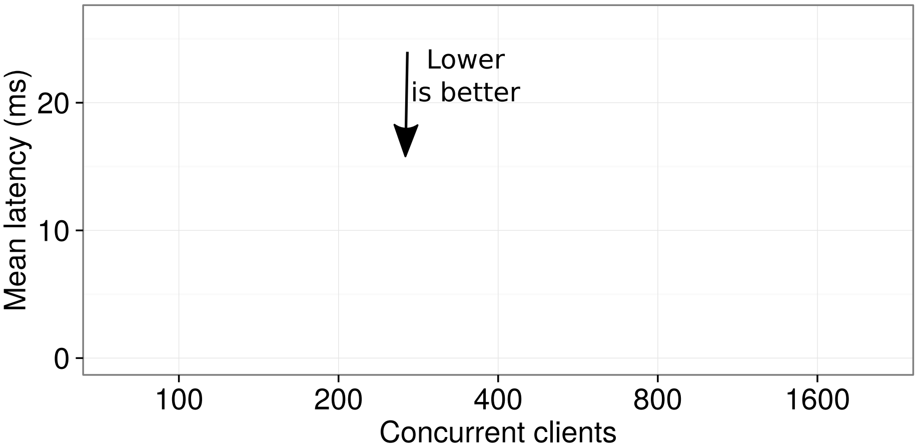


- Clients send HTTP requests up to ten backends.
- Persistent TCP connections to/from loadbalancer.
- Vary number of clients measure latency and throughput.
- DPDK/mTCP used to reduce kernel calls in connections.

Evaluation – latency (loadbalancer)



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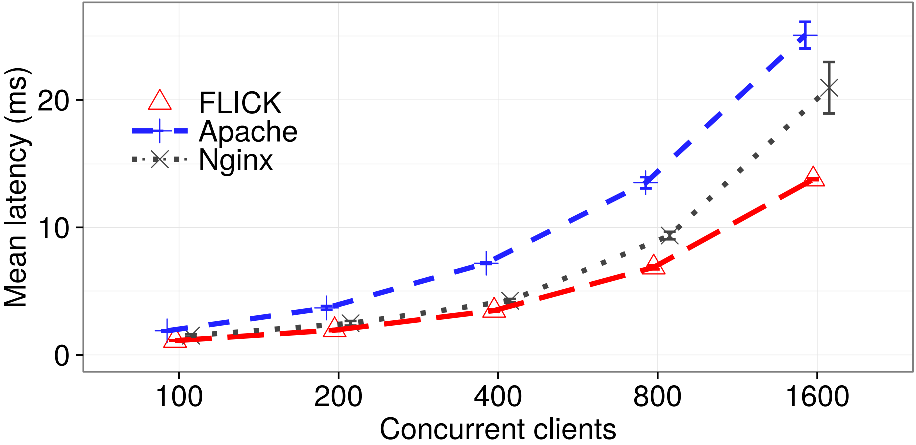

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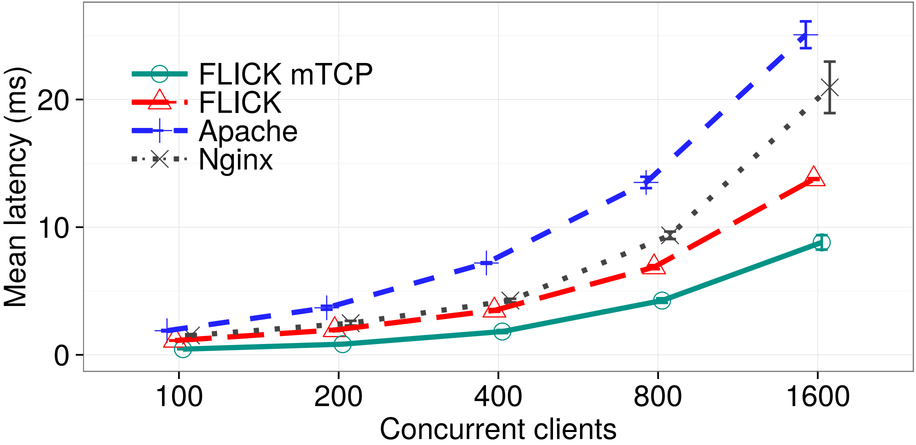
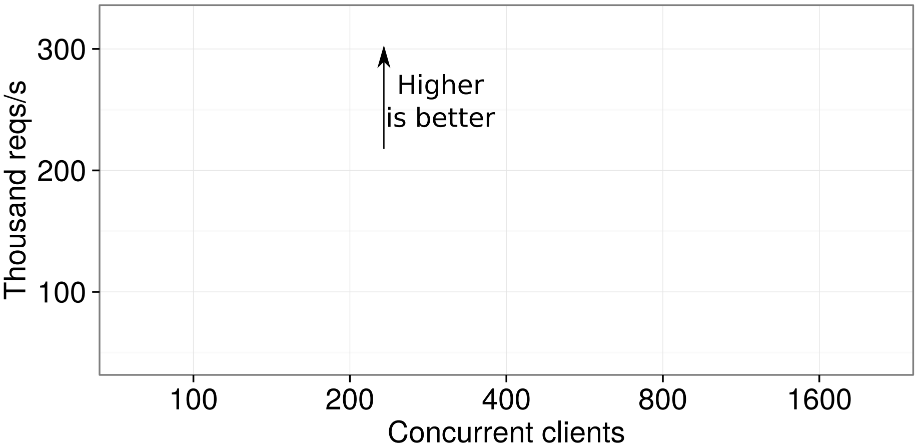


Evaluation – throughput (loadbalancer)



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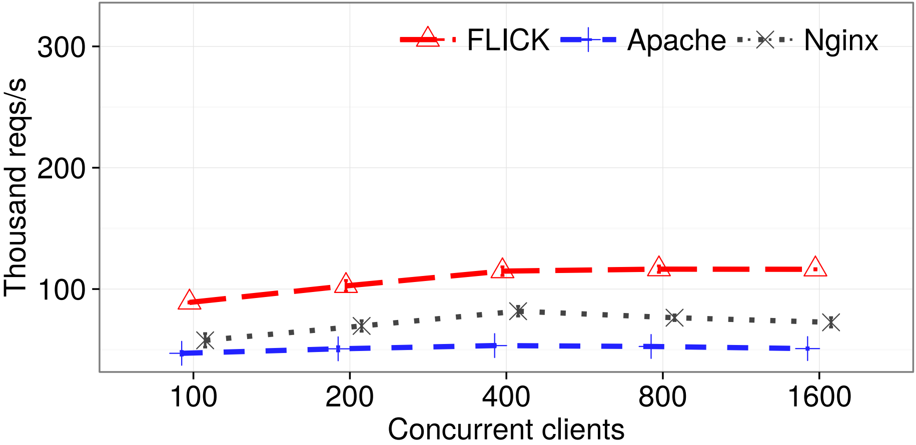

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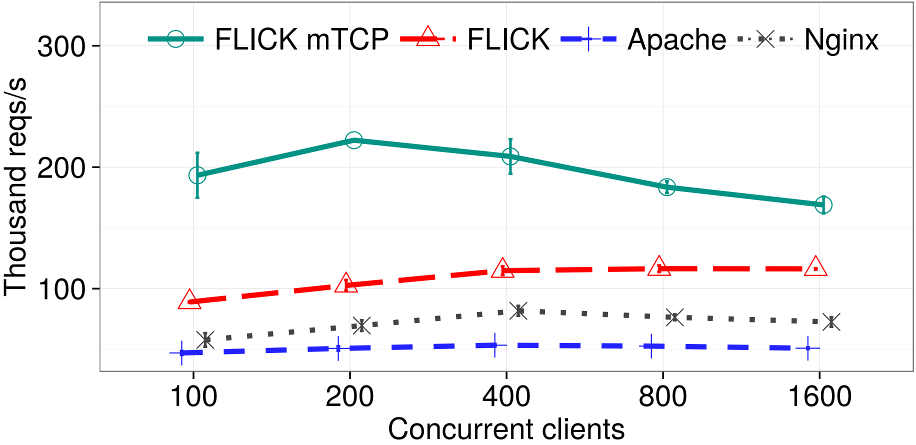
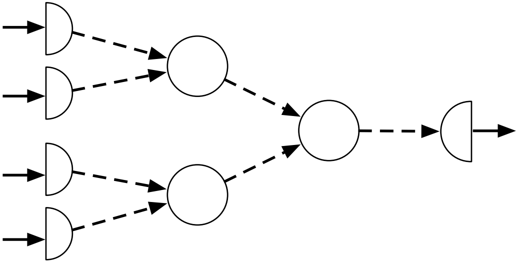


Evaluation – scalability with cores



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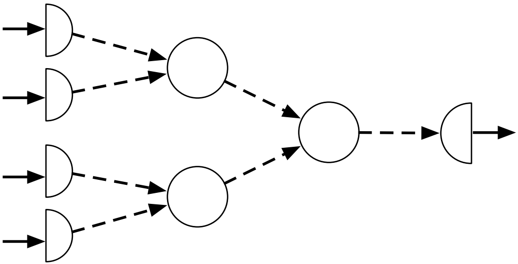
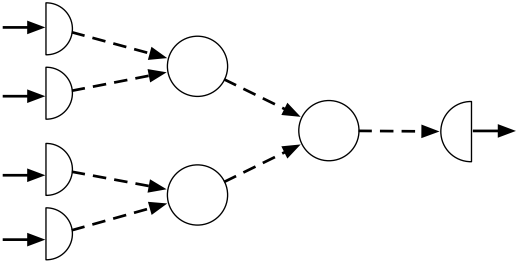


- This middlebox merges data in big data systems.
- Binary merge tree takes advantage of data parallelism.
- See "NetAgg: Using Middleboxes for Application-specific On-path Aggregation in Data Centres" [CoNext 2014].

Evaluation – scalability with cores



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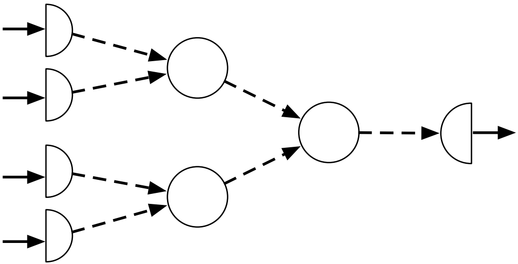
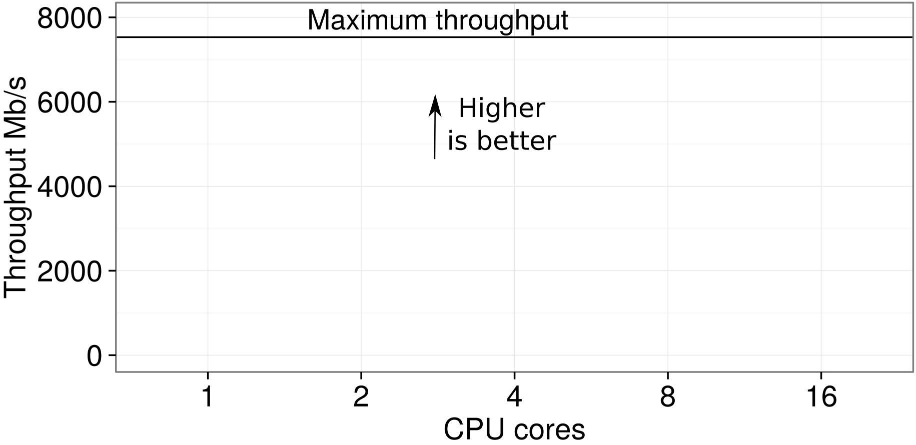


- Test scaling. Measure throughput as number of cores increases.
- Three data sets each one billion words. 8, 12 and 16 character words.
- Merge eight streams – measure throughput of output stream.

Evaluation – scalability with cores



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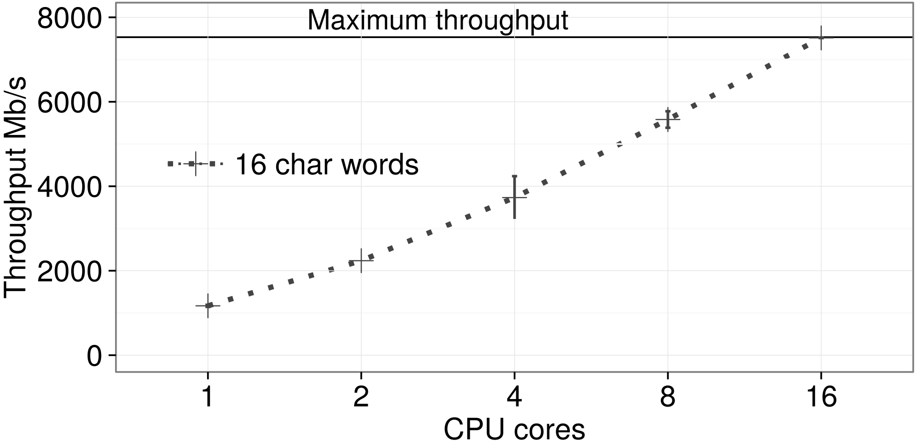

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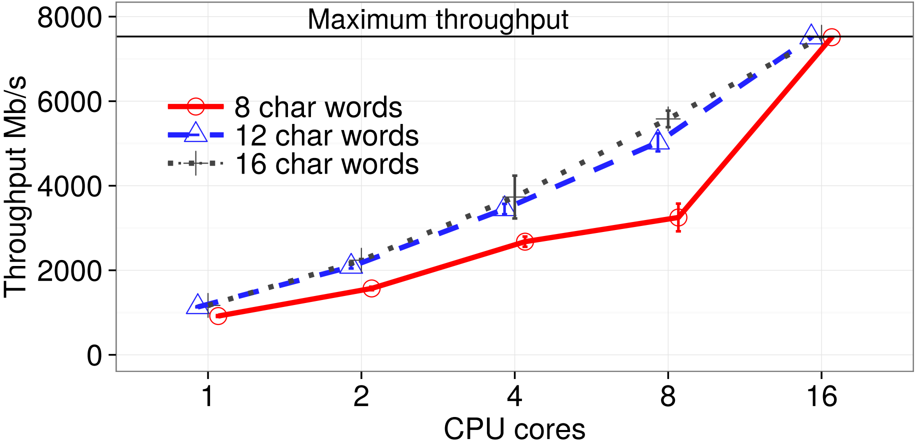

Conclusions

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Thank you – questions?

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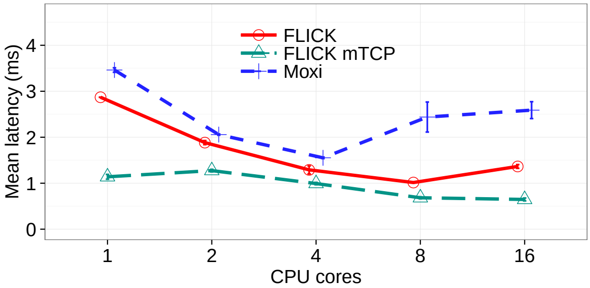
Performance – memcached example



- Comparison with Moxi (also supports multi-core + binary protocol).
- Set up 128 clients making multiple requests.
- Latency reduction shown.
- FLICK throughput with mTCP 198,000 reqs/sec.
- Moxi throughput 82,000 reqs/sec