Group Unicast for the Real World

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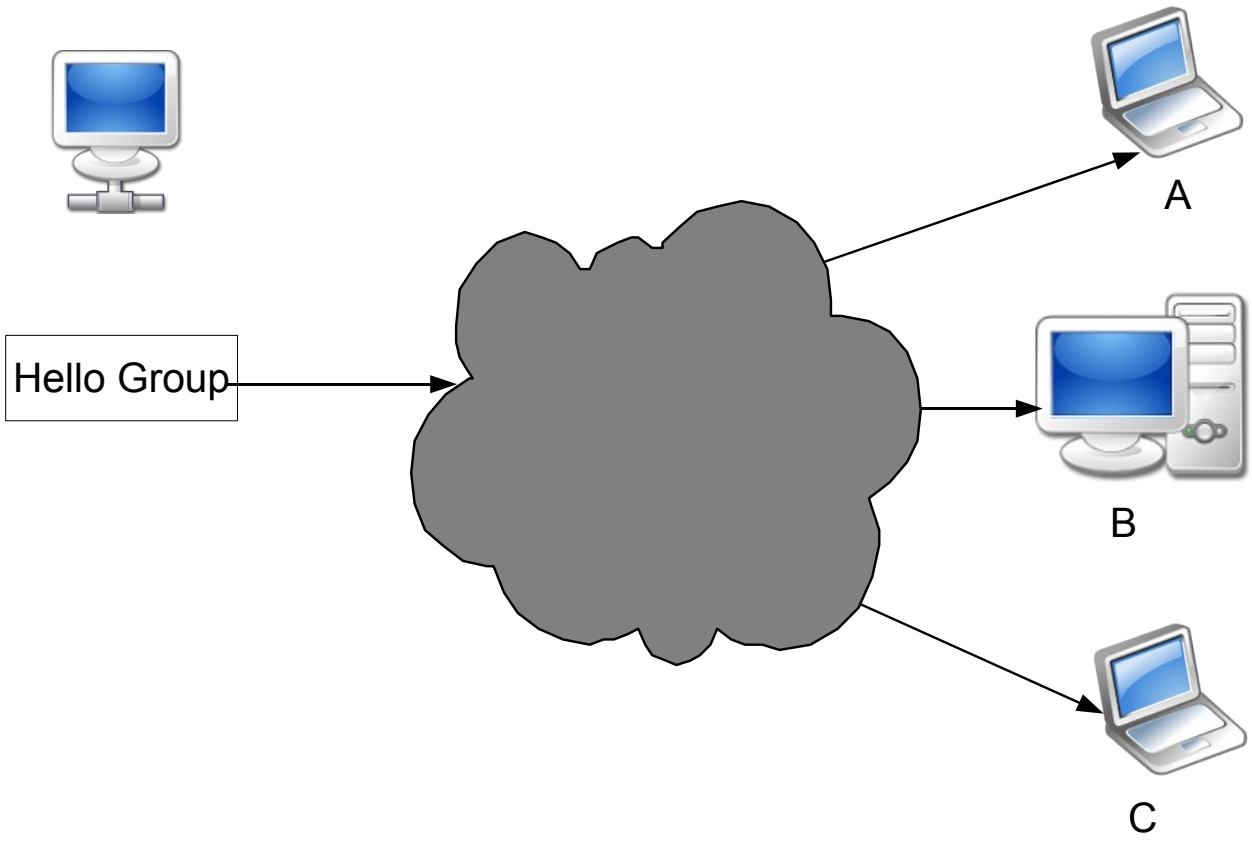
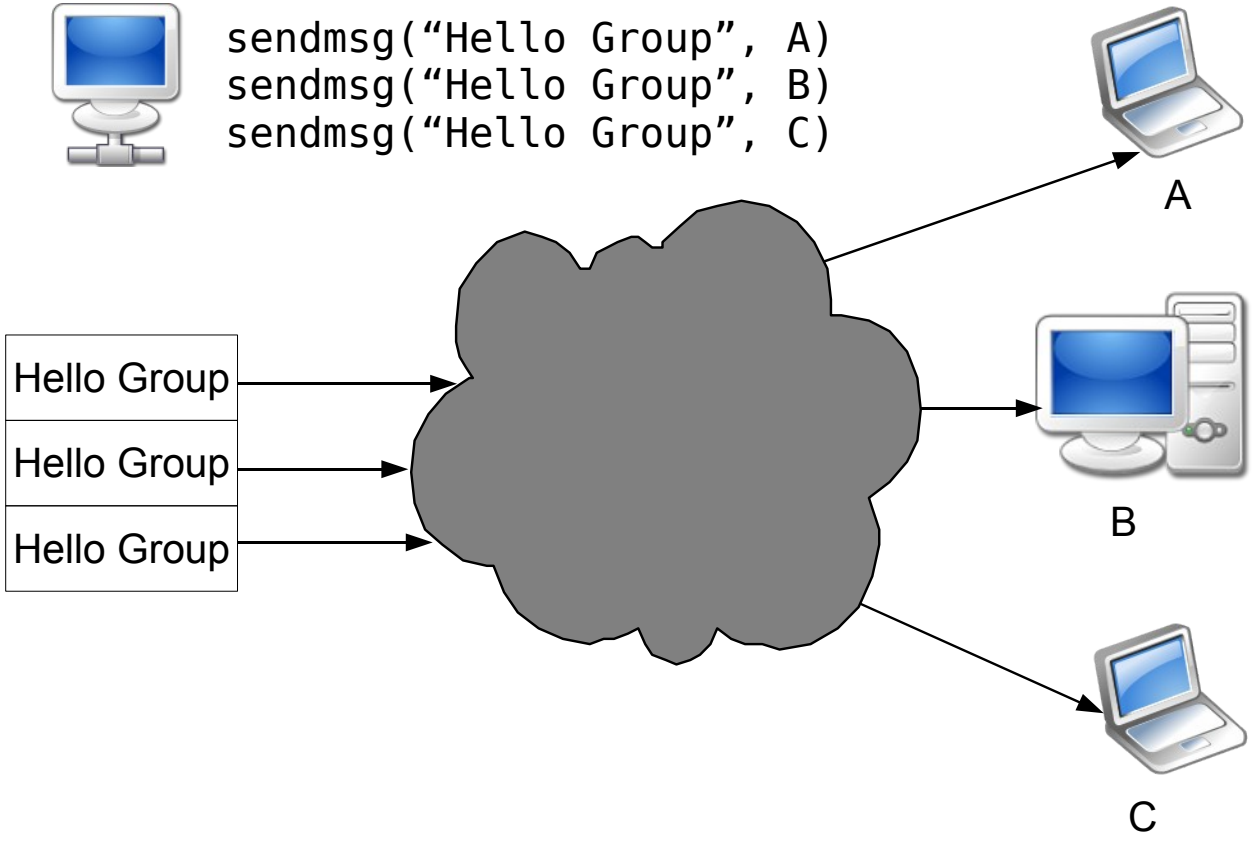
Goal

Transmit identical data to multiple recipients



Applications Live broadcasting, games, VoIP conferencing, ...

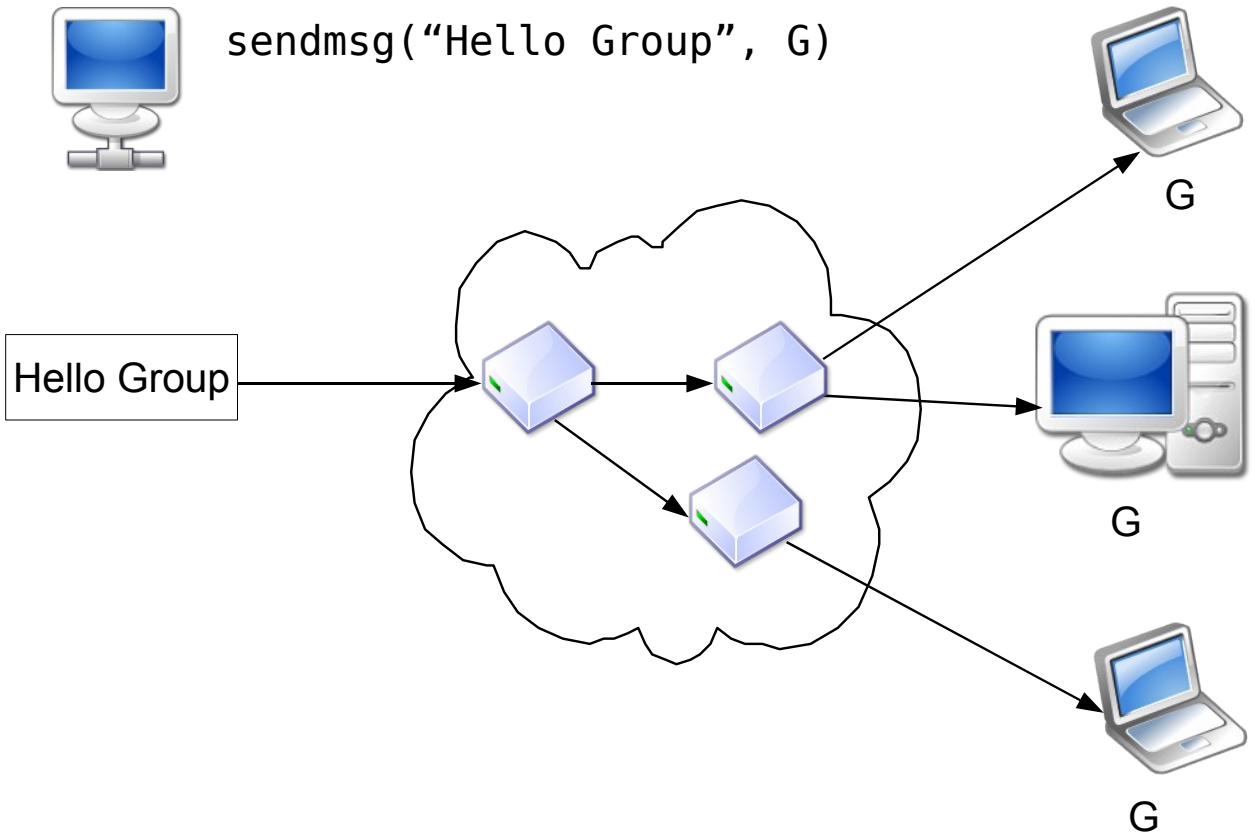
Solution 1: Multiple Unicast Transmissions



Problem Wastes both local and global resources

Solution 2: Multicast

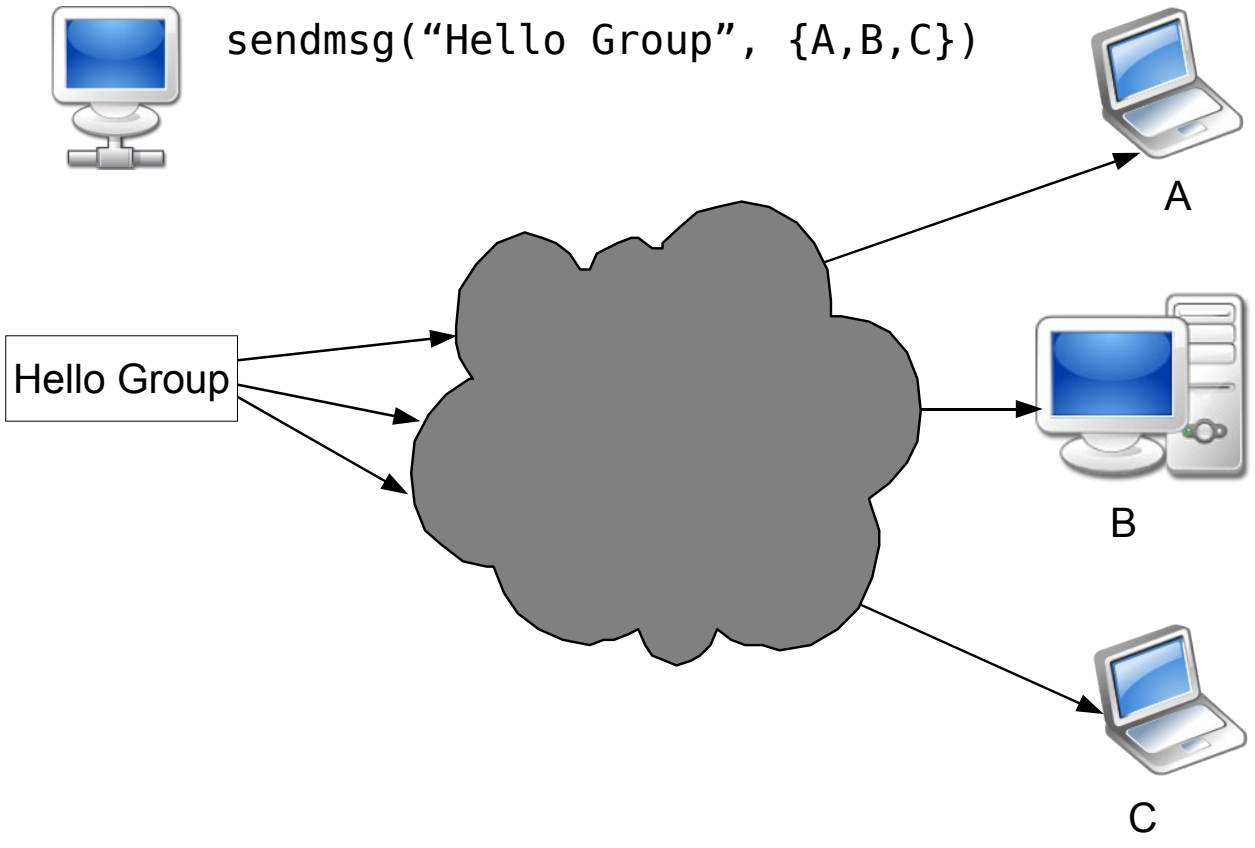
[Deering 1990]



Problem Lack of Internet support, costly for small groups

Solution 3: Group Unicast

[Karsten, Song, Kwok, Brecht 2005]



Benefits Reduces mode switches and memory copies in server

Important UDP only

Contributions

- Improved API and implementation
- Integration with a real-world media server
- Precise performance analysis

Interface Changes

Old Interface

- Group associated with UDP socket
- Use `send()` to transmit to group
- Use `setsockopt()` to manage group

New Interface

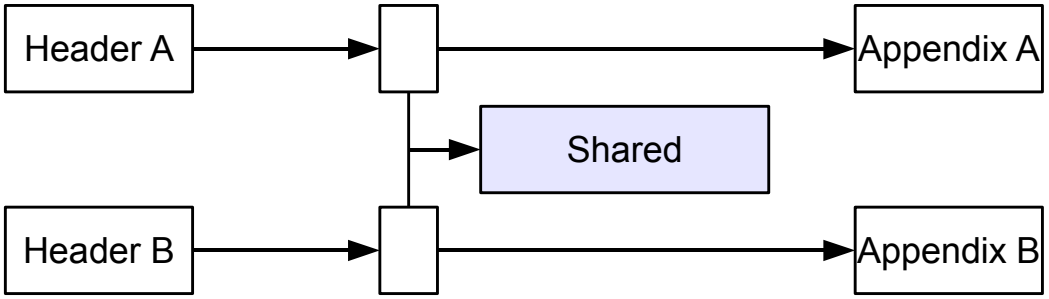
- New system call: `sendgroup()`
- No need for extra system calls to manage group
- Per-recipient private data

API

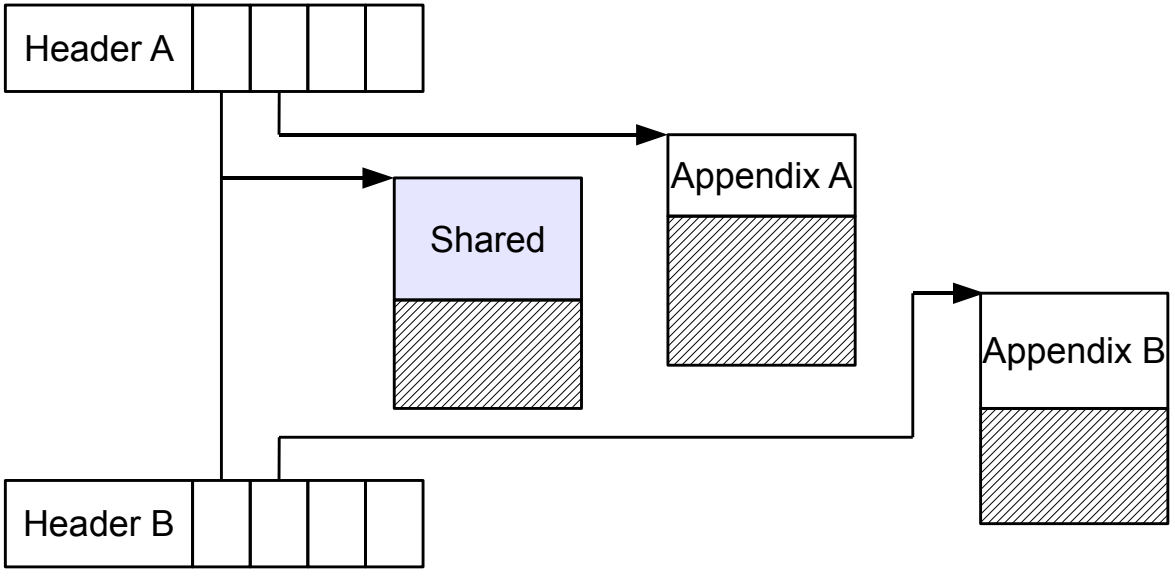
```
int sendgroup(int sd, struct giobuf* buf, size_t recnum,
              int flags, int* gerrno);

struct giobuf {
        struct iovec shared;          /* Shared data buffer */
        struct giovec recinfo[1];     /* Per-recipient info. */
};

struct giovec {
        struct sockaddr_in giov_dest; /* Destination address */
        struct iovec giov_prepend;    /* Prepended buffer */
        struct iovec giov_append;     /* Appended buffer */
};
```

Implementation

BSD: mbuf chain

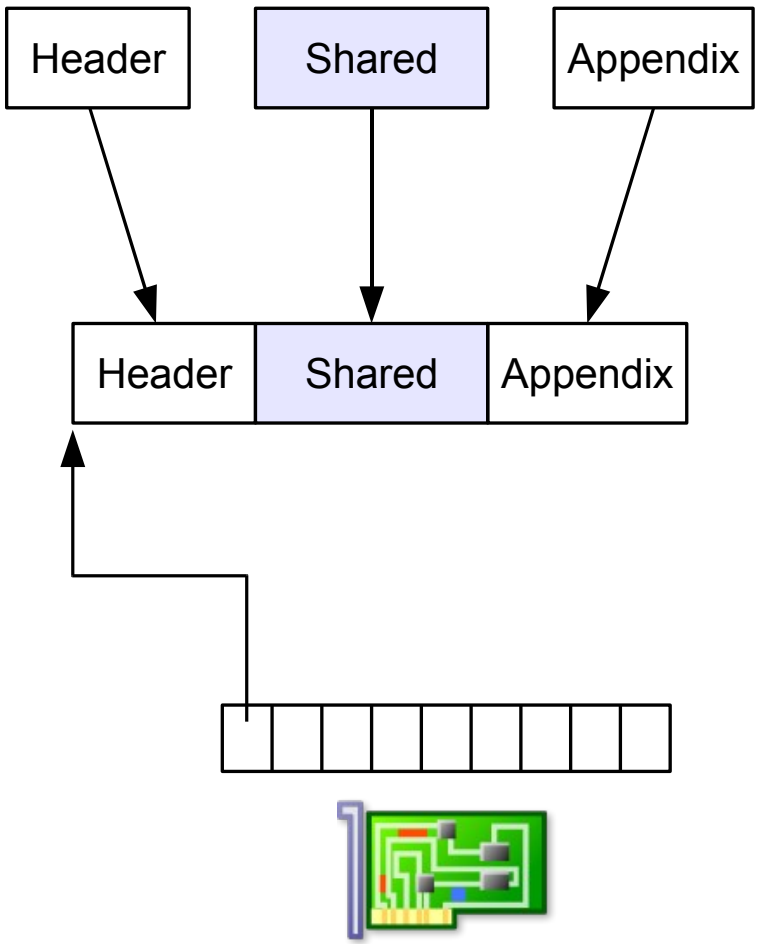


Linux: sk_buff + page pointers

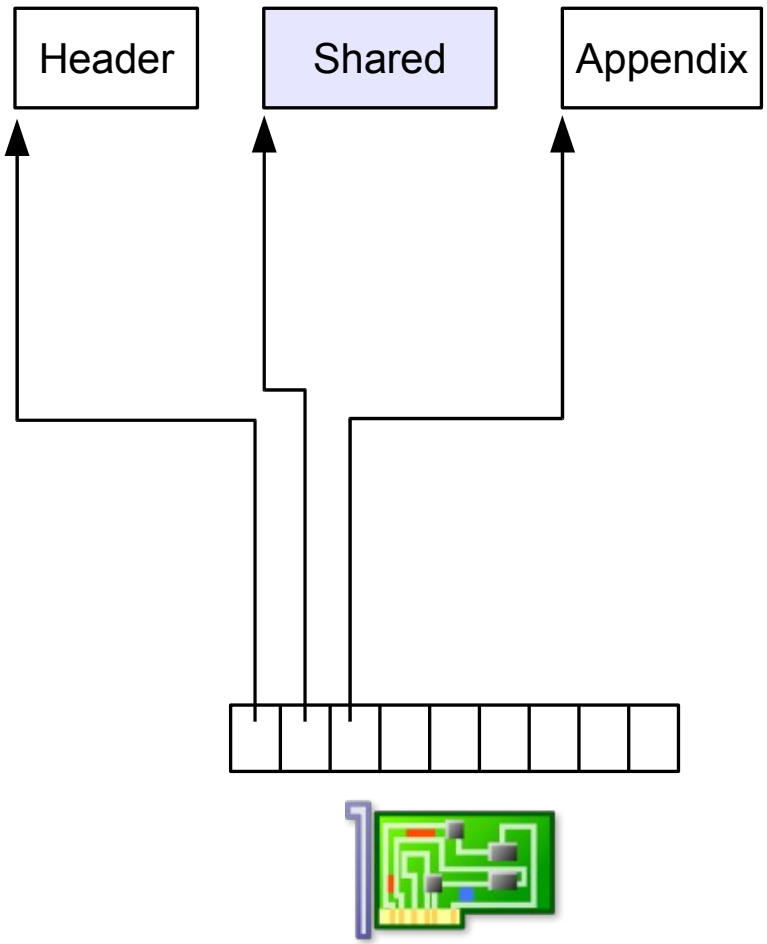


Implementation

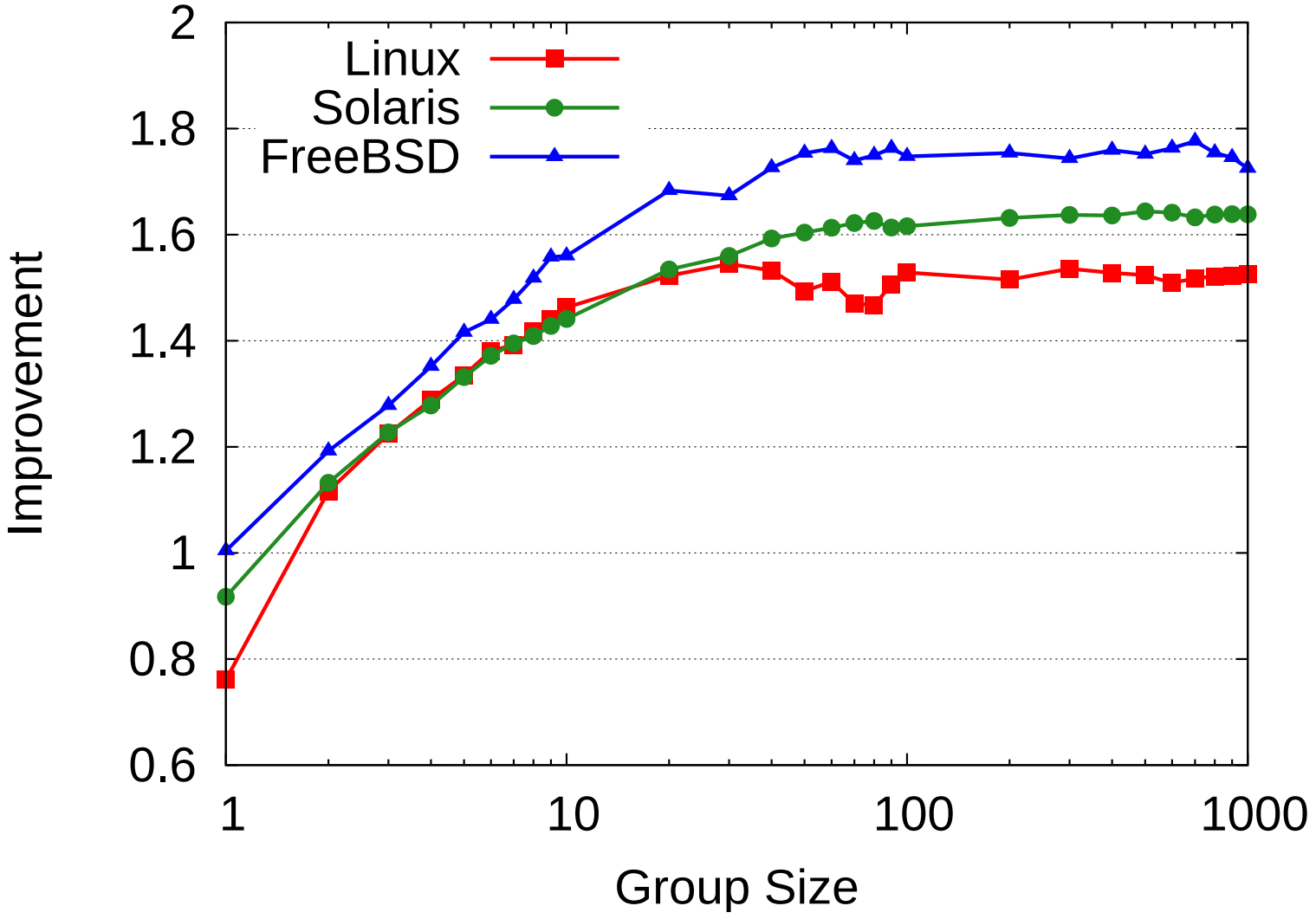
Without Scatter-Gather I/O



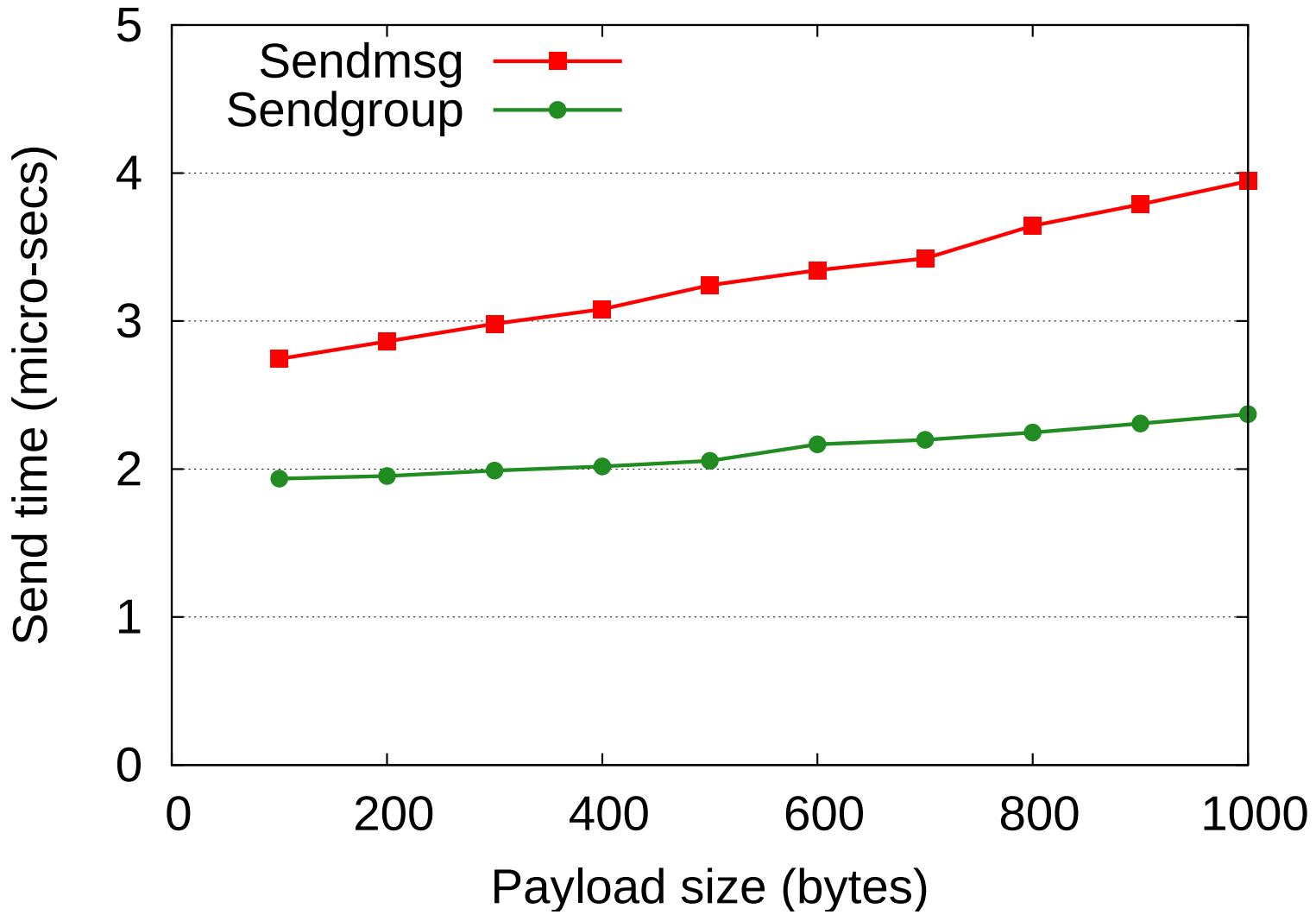
With Scatter-Gather I/O



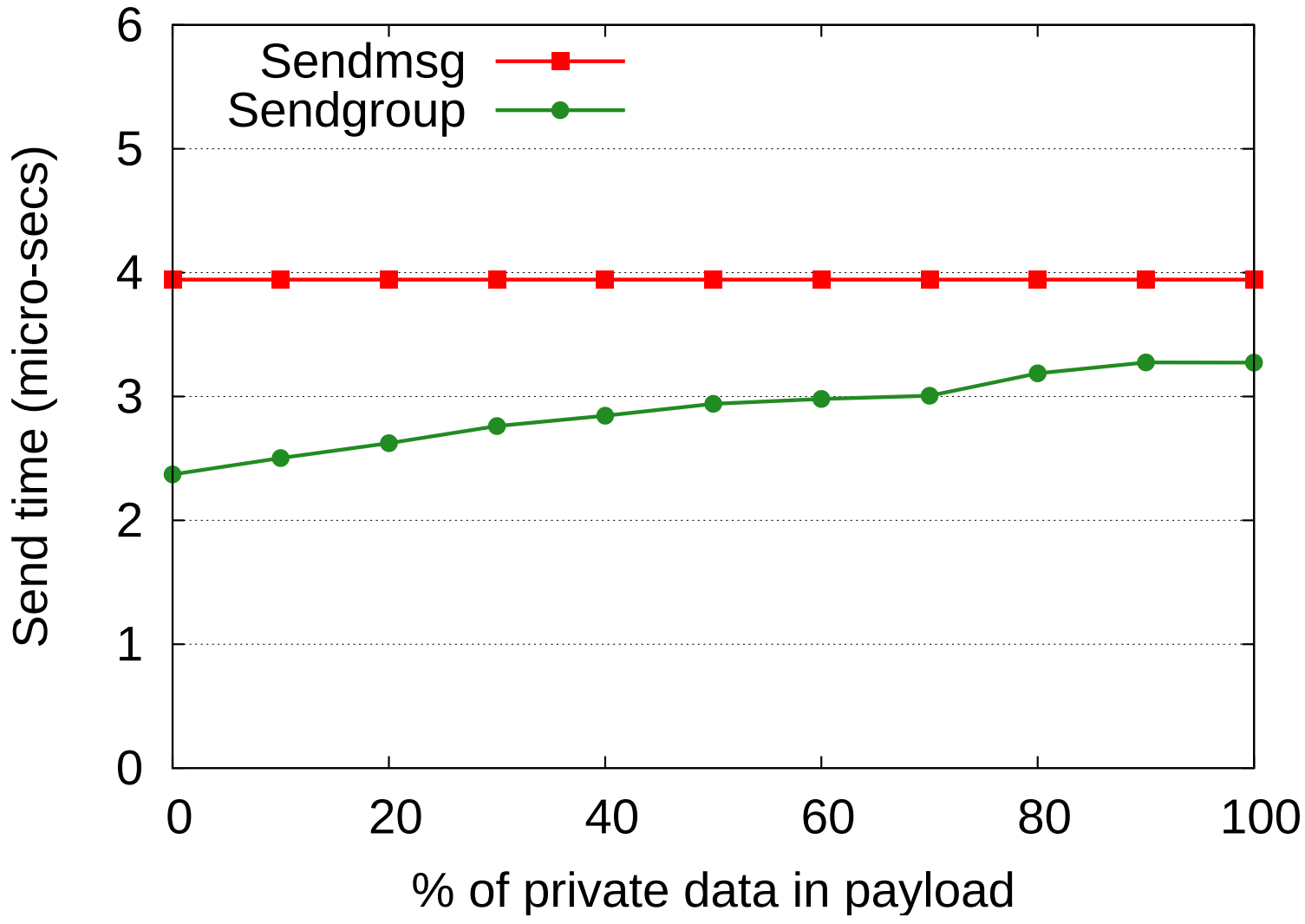
Micro-Benchmark: Improvement/Group Size



Micro-Benchmark: Packet Send-Time/Packet Size



Micro-Benchmark: Packet Per-Recipient Data



Integration with Real-World Applications

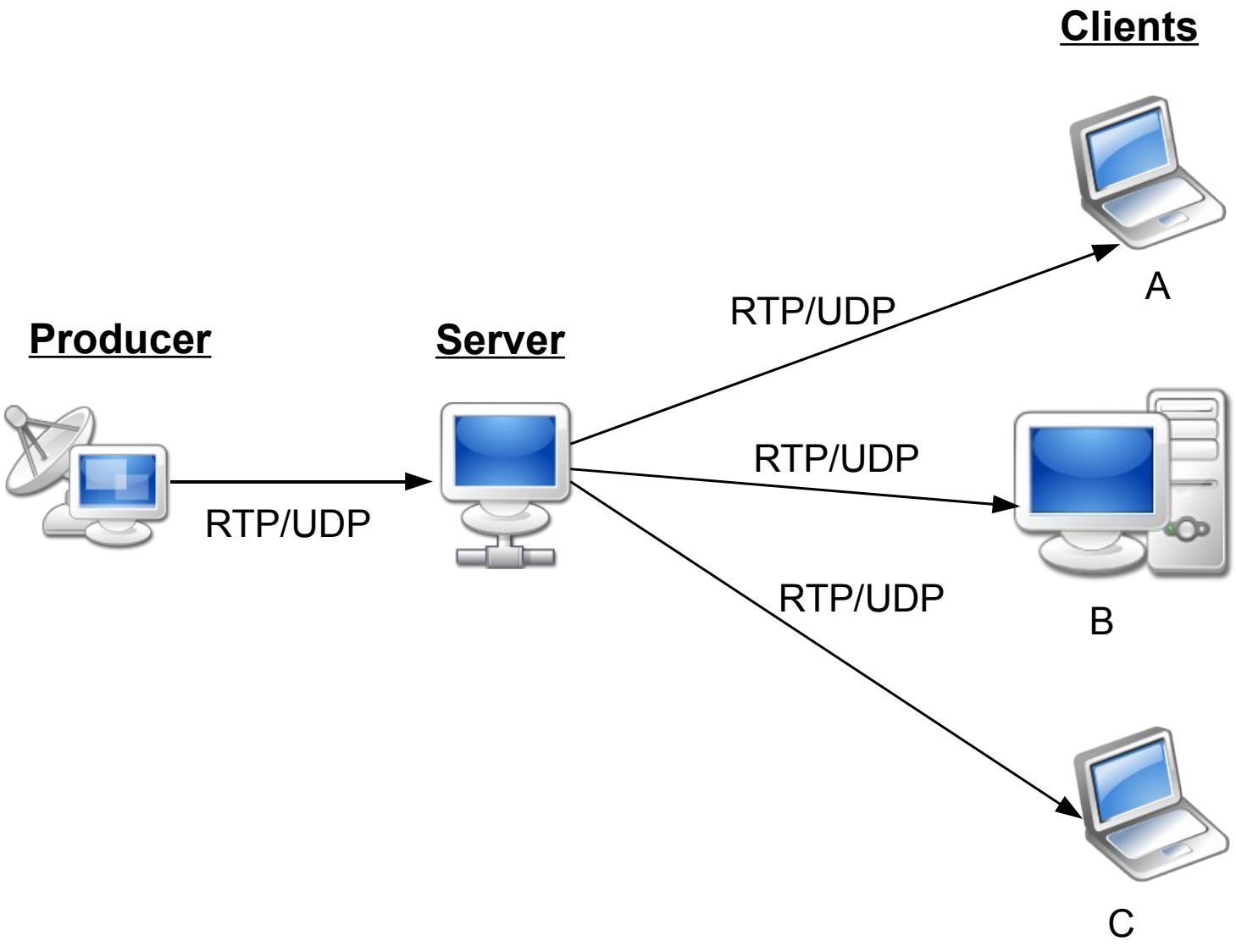
Show that `sendgroup()`:

- Is applicable
- Can be integrated
- Improves performance

The Helix Server

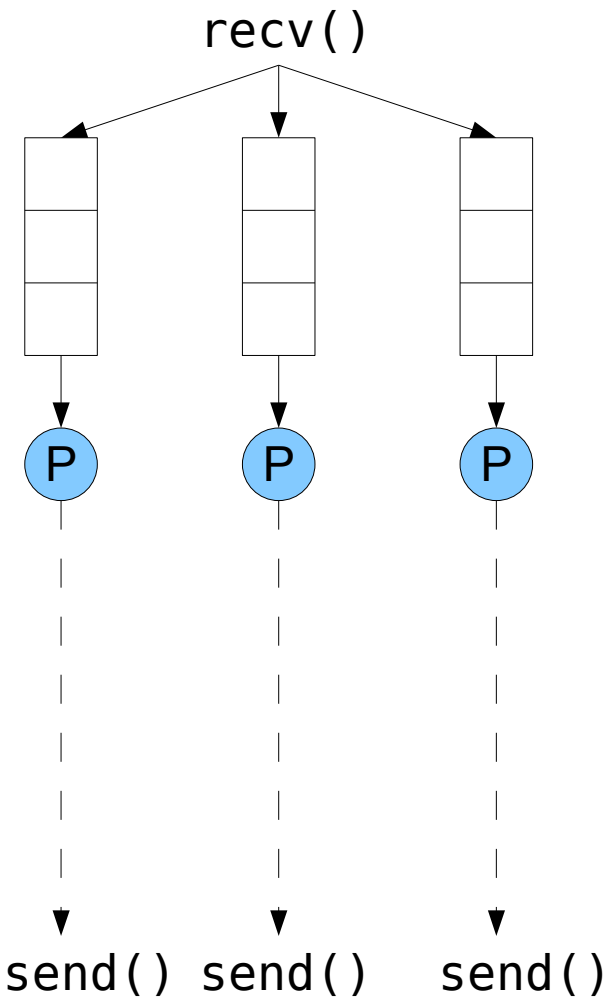
- Multimedia server from Real Networks
- Open source version of the Real Server
- Handles both on-demand and live content
- `https://helix-server.helixcommunity.org`

Helix Live-Broadcasting

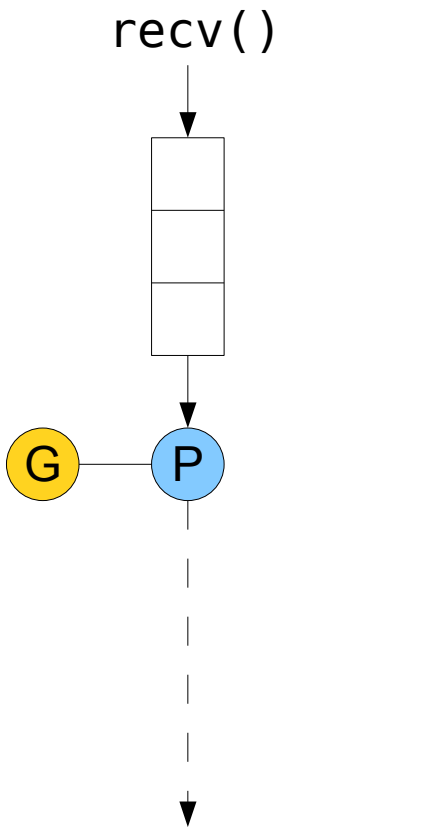


Helix-sendgroup() Integration

Original Helix

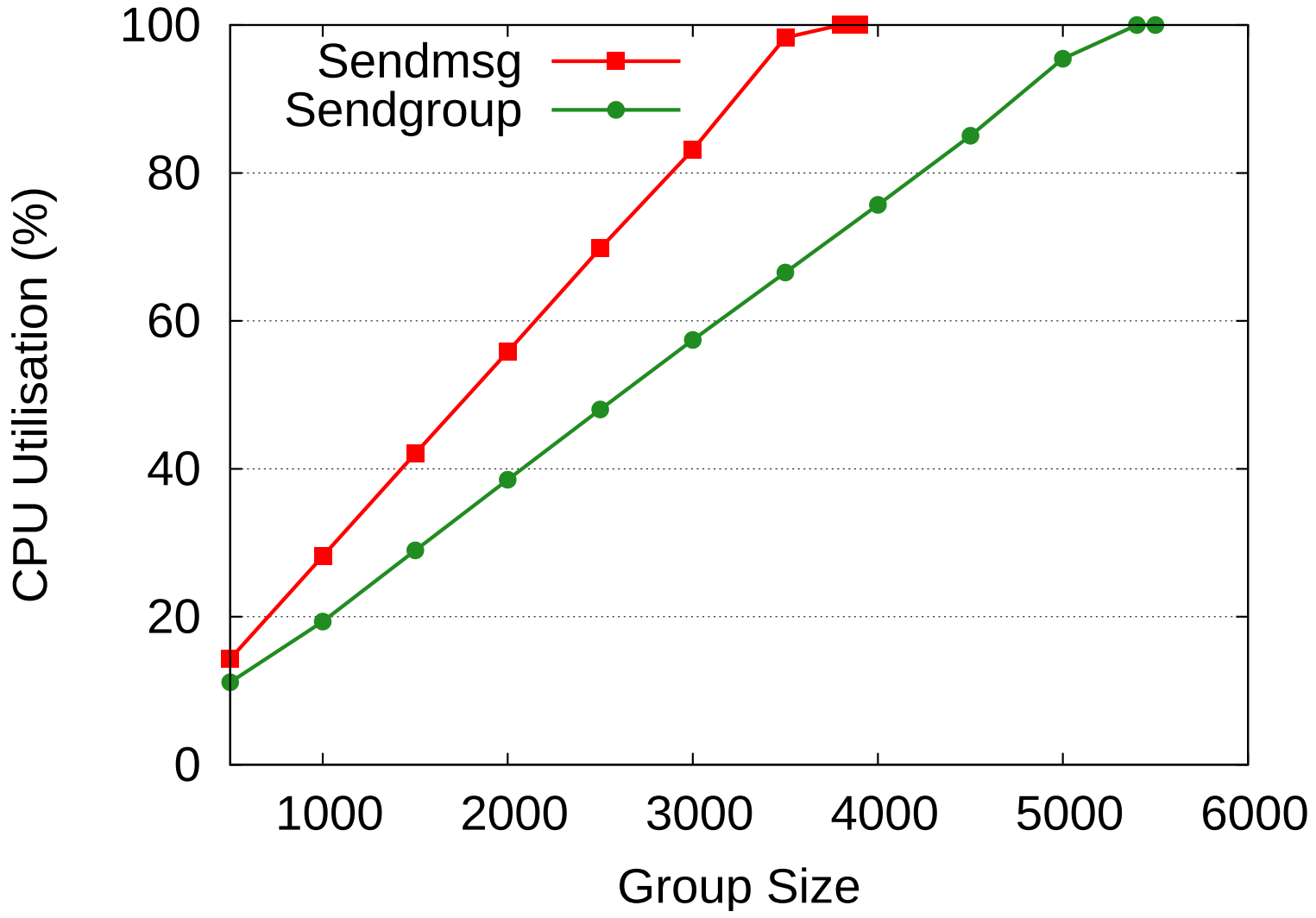


Modified Helix

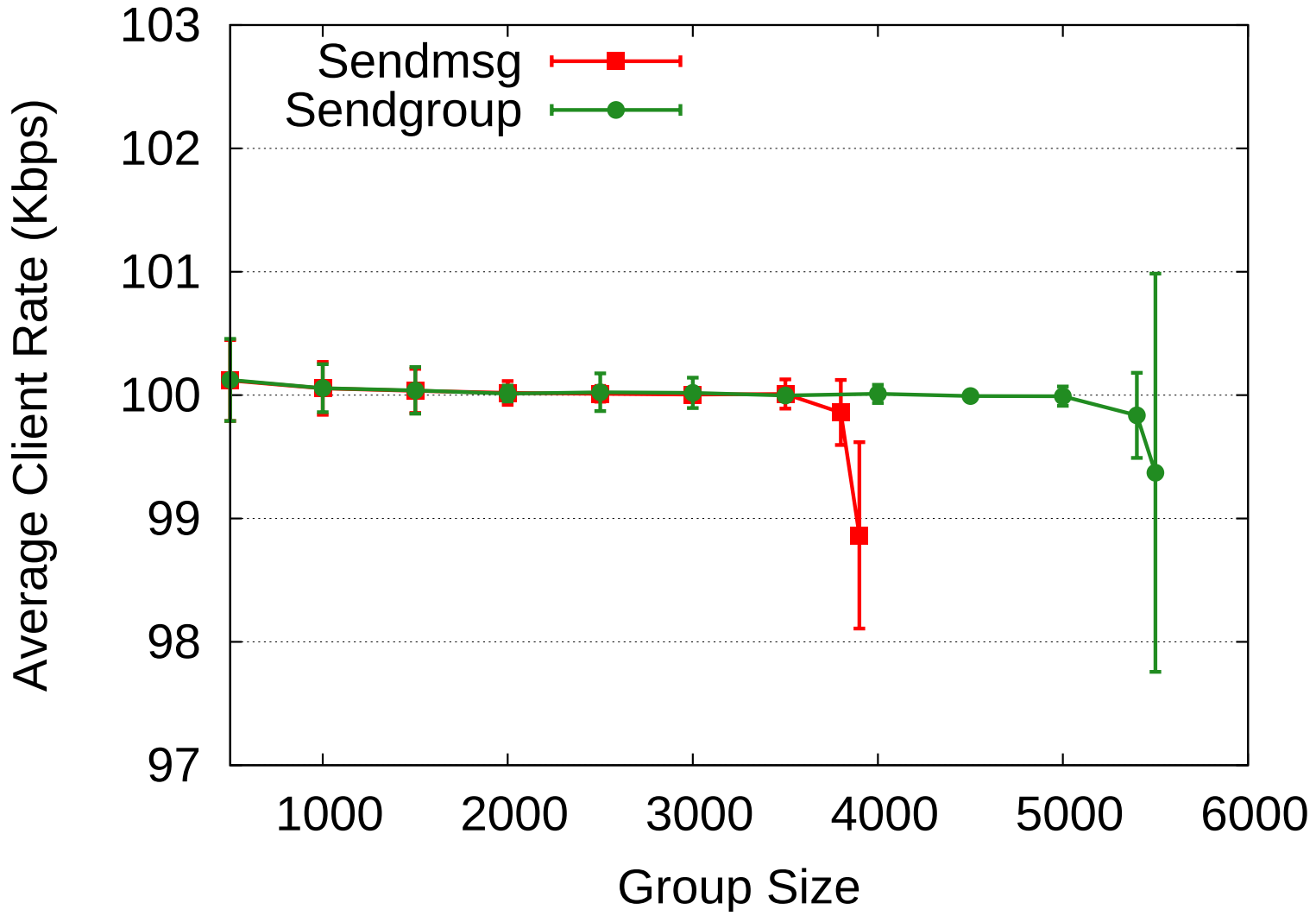



```
foreach client {
    send()
}
```

Helix Benchmark: CPU Utilisation/Group Size



Helix Benchmark: Client Rate/Group Size



Performance Analysis

- **Micro-benchmarks:** Determine speed-up of `sendgroup()` over `sendmsg()` loop
- **Helix:** Measure execution time of `sendmsg()` loop
- **Amdahl's law:** Predict overall Helix improvement
- **Confirmation:** Compare to observable overall Helix improvement

Amdahl's Law in Action

- Group size: 1000
- Payload size: 1000 bytes
- `sendgroup()` speed-up: $s = 1.664$ (from micro-benchmarks)
- Fraction: $f = \frac{T_{sc}+T_{irq}+T_{bh}-T_{sleep}}{T_{exp}} = 0.791$
- Expected overall speed-up:

$$r = \frac{1}{1-f+\frac{f}{s}} = \frac{1}{1-0.791+\frac{0.791}{1.664}} = 1.461$$

- Observed speed-up: $\overline{r} = 1.45$

Conclusions

- `sendgroup()` has real-world applications
- Noticeable performance improvement in certain scenarios
- Avoiding mode switches is good
- Avoiding memory copies even better
  - Direct effect on system call execution path
  - Also beneficial to entire environment
- Better analysis of system calls $\Rightarrow$ more accurate predictions