XCP-i: eXplicit Control Protocol for heterogeneous inter-networking of high-speed networks

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eXplicit Control Protocol [Katabi]

- Protocol based on the use of assisted routers (generalizes ECN).
- XCP Header: TCP Header + 3 new fields.
- The XCP routers update the $H_{feedback}$.
- The feedback is sent back to the sender in the ACK.
- The sender updates the $cwnd = cwnd + feedback$.

\[
feedback = \alpha \cdot rttsr \cdot (O_r - I_r) - \beta Q
\]
\[
\alpha = 0.4, \beta = 0.226
\]

$Q$: persistent queue size
XCP vs TCP

Simulation on ns-2.

XCP always more performant than TCP.
But...

1. It works well only in 100% XCP networks.
2. No interoperability between equipments
   - Bad performance if classical IP routers are placed in the bottleneck.
3. No interoperability between protocols
   - Throughput really small when it shares the bottleneck with end-to-end protocols.
4. Impossible to think in a decremental deployment.
XCP Router - IP classical router

![Diagram showing network with XCP routers and a non-XCP router]

- Sender: 80 Mbps, 1 ms
- XCP: 80 Mbps, 16 ms
- Non XCP router: 30 Mbps, 16 ms
- XCP: 80 Mbps, 1 ms
- Receiver

![Graph showing throughput over time]

- Y-axis: Throughput (Mbps)
- X-axis: Time (s)

XCP - XCP routers/IP routers
XCP Router - IP classical router

Less performant than TCP!
The absence of interoperability prevents the incremental deployment of XCP in the new networks.

Our approach enables to tackle the problem:

- with no states per flow in the routers.
- keeping the original control laws of XCP.
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Our approach enables to tackle the problem:

1. with no states per flow in the routers.
2. keeping the original control laws of XCP.

1. Where are placed the non XCP routers?
Detecting the non XCP clouds

- Use the IP TTL field.
- New field xcp_ttl in the XCP header.
- Initialize it with the same TTL value.
- Compare fields xcp_ttl and TTL.
- Decrease xcp_ttl in every XCP-i router.

xcp_ttl = TTL
Detecting the non XCP clouds

- Use the IP TTL field.
- New field `xcp_ttl` in the XCP header.
- Initialize to the same TTL value.
- Compare fields `xcp_ttl` and `TTL`.
- Decrease `xcp_ttl` in every XCP-i router.

\[
xcp_{ttl} = TTL \quad xcp_{ttl} == TTL \quad xcp_{ttl}-- \quad TTL--
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Detecting the non XCP clouds

Discover the non XCP routers:

- Use the IP TTL field.
- New field \texttt{xcp\_ttl} in the XCP header.
- Initialize to the same TTL value.
- Compare fields \texttt{xcp\_ttl} and TTL.
- Decrease \texttt{xcp\_ttl} in every XCP-i router.

\[ \texttt{xcp\_ttl} = \text{TTL} \quad \texttt{xcp\_ttl} == \text{TTL} \]
\[ \texttt{xcp\_ttl}-- \quad \text{TTL}-- \]
\[ \texttt{xcp\_ttl} != \text{TTL} \quad \text{TTL}-- \]
\[ \texttt{xcp\_ttl} = \text{TTL} \]

2. What is inside the non-XCP cloud?
Computing the resources in the non-XCP cloud

- Compute the state of the network in the non-XCP cloud (R0 -> R2).
  - Execute a processus to compute the available bandwidth in the non XCP cloud (Packet train, quickprobe).
- Discover the last XCP-i router (R0).
  - New field `last_xcp_router` in the XCP header.
  - Update it with the IP address of the last sender node.
Computing the resources in the non-XCP cloud

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```plaintext
last_xcp_router_ = S S R0
```
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3. How to calculate a new feedback to take the ABW into account?
The Virtual XCP-i router

- Send the Available BW to the router which required it.
  - Hash table.
- Create a virtual router XCP-iv.
  - $f = \alpha \cdot rtt \cdot (O - I) - \beta \cdot Q$
  - $f_v = \alpha \cdot rtt \cdot ABW - \beta \cdot Q$
- Substitute every non-XCP cloud by a virtual router.
XCP-i in an heterogeneous network

- Simulation in ns-2.
- Adapted performance in a not fully XCP network.
XCP-i in an heterogeneous network

- Simulation in ns-2.
- Adapted performance in a not fully XCP network.

- Good fairness between flows.
- Flows stability.
Sensibility to the bandwidth estimation accuracy

- Under estimation.
  - Under utilisation.
  - No timeouts.
- Over estimation.
  - Timeouts depend on the routers capacity.

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Conclusion

- Approach for the interoperability between equipements in an heterogeneous network.
- XCP-i is the first step to an interoperable congestion control protocol based on assisted routers.
- XCP-i keeps the XCP controls laws as in the original model.
- XCP-i works in a large range of network topologies.
Future Works

- Implementation of XCP-i in a Linux kernel.
- Deployment and testing of XCP-i on a large scale (grid5000).
- Fairness with end-to-end protocols.
Discussion Time...!