A Highly Reliable and Programmable Software Defined Coalition (SDC) Architecture using Multiple Control Plane Composition with Distributed Verification

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Problem

State-of-the-art

- Traditional distributed MANET routing protocols such as OLSRv2 are robust but not flexible (e.g., supports only shortest path routing)
- Logically centralized control such as software-defined networking (SDN) provides flexibility but is not robust (e.g., when fragmented or weakly connected)

Coalition needs/benefits

- Highly robust SDC control architecture for assured communications in challenging tactical communication settings
- Highly flexible control to realize flexible traffic engineering, support mission-aware, dynamic service differentiation, and integrate beyond routing such as security functions

Approaches

~~Build a better control plane?~~

Going beyond to use multiple control planes!

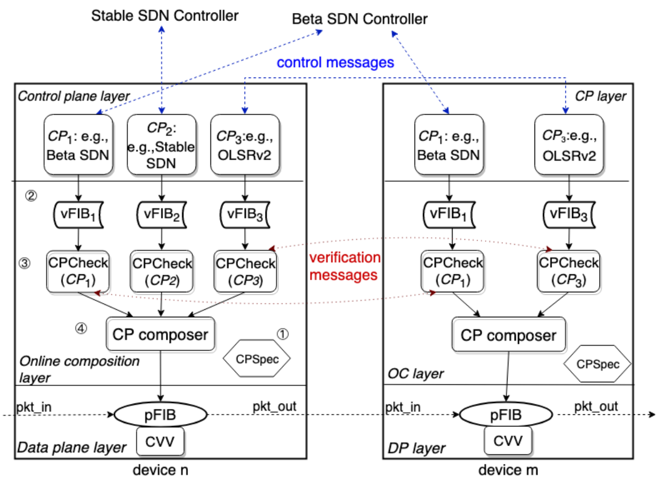

Figure 1: Carbide architecture.

> Insight: Instead of using a single control plane, *Carbide* composes multiple control planes to obtain the properties desired. Such composition is not a new idea--it is the basic idea of alloys, hence we name the architecture *Carbide*.

- Virtualize each Control Plane (CP) as a black box
- **CPSpec**: correctness requirements
- **vFIB**: virtual forwarding information
- **CPCheck**: a light-weight event-driven verification module associated with each CP
- **CP composer**: real-time computation of the configuration to enforce at the data plane layer
- **pFIB**: physical FIB that processes data packets at line rate
- **CVV**: control plane visiting vector tag to prevent forwarding loops for data packets by setting sufficient conditions

- Related manuscripts can be found at: https://dais-ita.org/node/3940

A Simple Example

- **Security requirement:** all flows must traverse node B (e.g. break and inspect gateway)
- **Controller disconnected:** B-E failure => network partition => controller disconnection => SDN forwarding rules expired

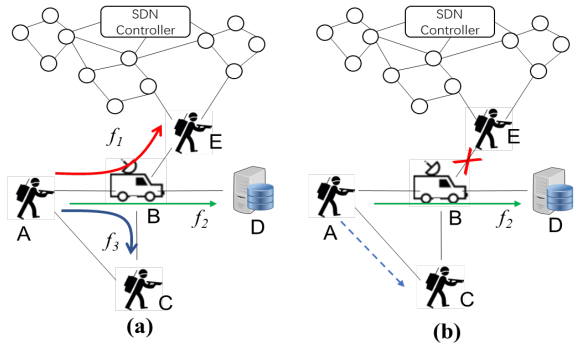

Figure 3: (a) Before failure, (b) After failure at B-E.

- (a) f_1, f_2 and f_3 are set up by CP_1 (SDN), satisfying security requirement
- (b) f_1 becomes unavailable because of the partition; f_2 is served by CP_2 (OLSRv2), satisfying security requirement; f_3 is blocked by Carbide because it is insecure

Military & Coalition Relevance

- Improve robustness, reduce misconfigurations, and avoid security risks in complex, dynamic, contested settings.
- Improve overall agility and tempo of operations.
- Achieve "assured security" and "assured communications".

Evaluation & Implementation

- Rocketfuel Topology, 157 nodes
- Two CPs: an SDN, OLSRv2
- Local verification updates less than 2.5 ms

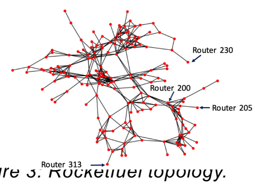

Figure 5: Rocketfuel topology.

	SDN	*Carbide*	OLSRv2
Average Downtime	27.34 ms	9.65 ms	42.53 ms

Figure 4: Failure recovery performance comparison.

Summary & Future Work

- *Carbide*: a novel, fundamental control architecture for SDC using the composition of multiple control planes
- Benefits: reliability, flexibility, optimality
- Future work: implementation on military physical devices

Publication & Impact

- [DAIS'19] Geng Li, Akrit Mudvari, Kerim Gokarslan, Patrick Baker, Sastry Kompella, Franck Le, Kelvin Marcus, Vinod Mishra, Jeremy Tucker, Paul Yu and Yang Richard Yang, "Magnalium: Highly reliable SDC Networks by Composing Multiple Control Planes".

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