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CS&P Workshop 2021

Attack trees with Time Constraints

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A real-time attack on systems require a real-time measure to stop (or reduce the damage) the attack.

Plan of Talk

Attack Trees

Challenges

Time constraints

Attack trees to timed automata

Conclusion

Definition

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- capture i.e., identifying root cause of threats (attacks)
- classify i.e., shows the breakdown of threats and how they can be achieve
- share i.e., study how to repel the attacks.

Tree structure

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- Root node represent the attack target
- internal nodes (child nodes) are conditions which must be satisfied to reach the root, and
- leaf nodes are atomic actions that need to be carried out to initiate the attack
- nodes (except for leaves) are associated with gates refinement e.g *AND* and *OR* gates (can be easily extended to show sequential actions *SAND*,*SOR*)

Attack tree example 1

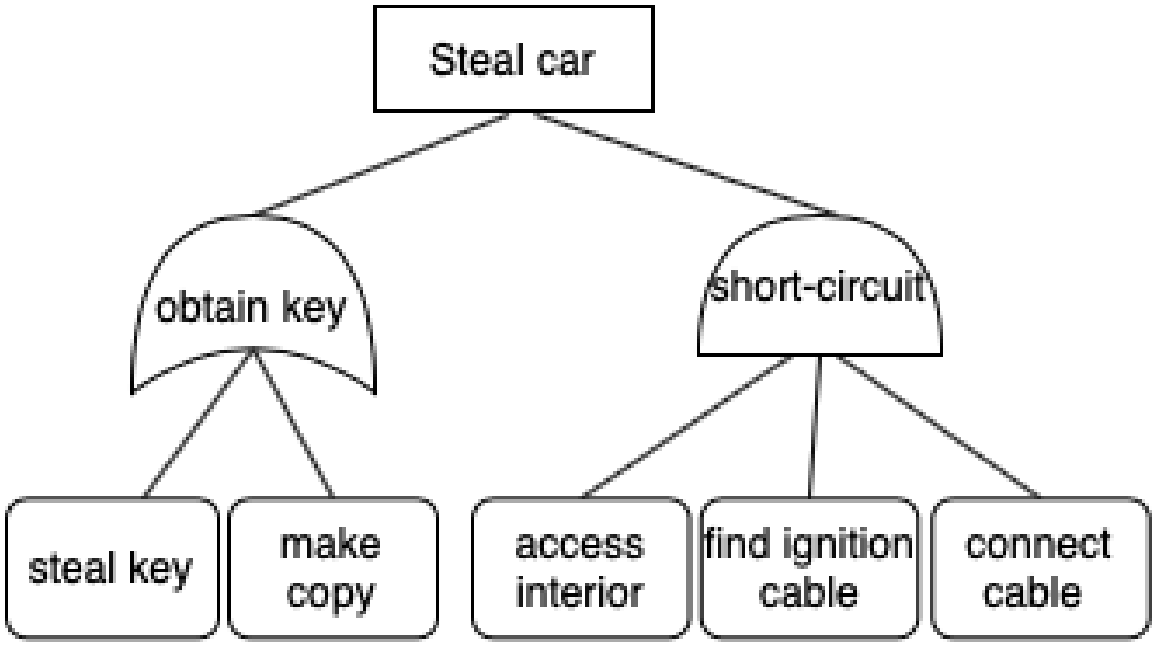

Figure: A simple example of attack tree

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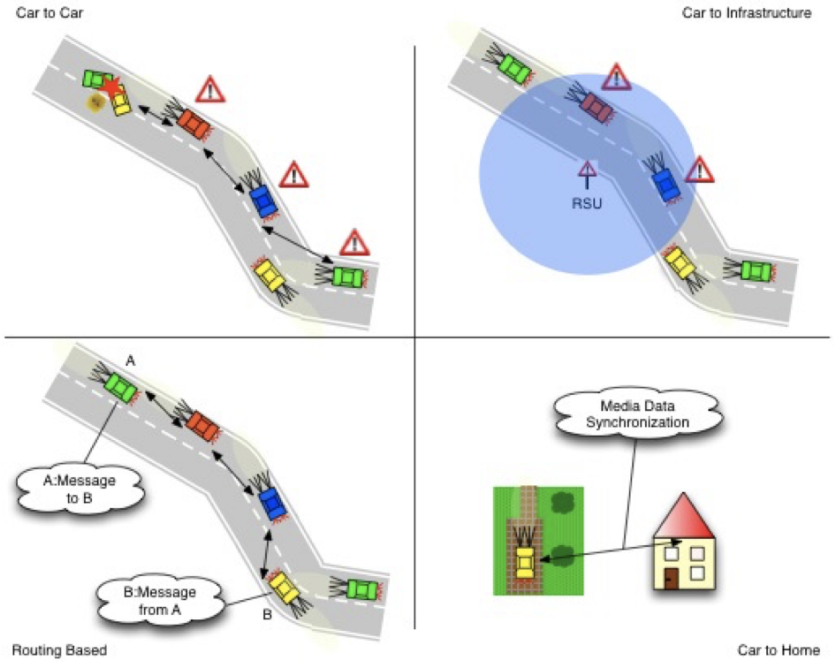
- study and identify the possible attack paths that can be easily exploited [S. Haque et. al.]
- attack-defence and countermeasures to prevent attack from happening [Kordy, B et. al.]

Dynamic threat environment

Dynamic threat environment

Most assets are no longer stand-along i.e., interacts with other set of systems and objects from the physical environment, e.g CPS.

Attack trees analysis
problems



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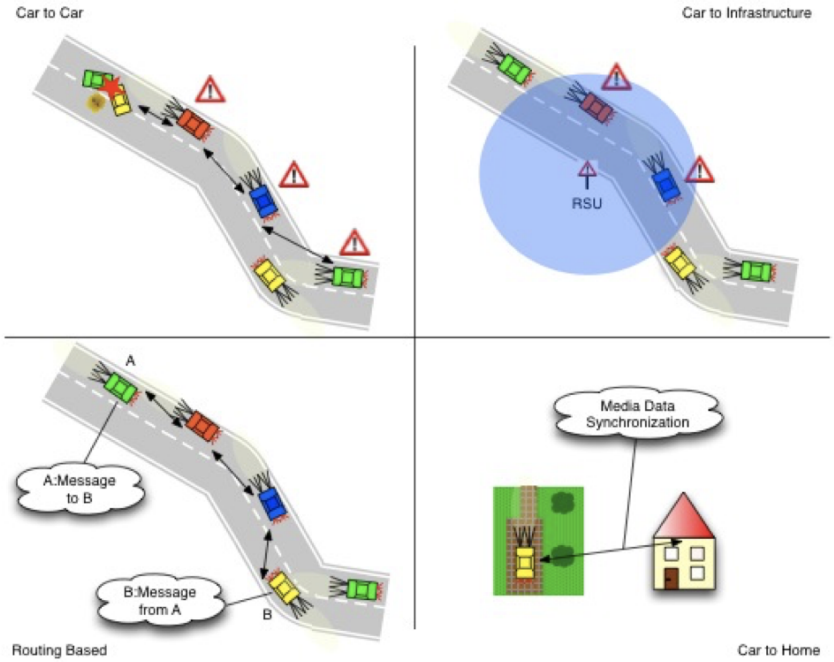

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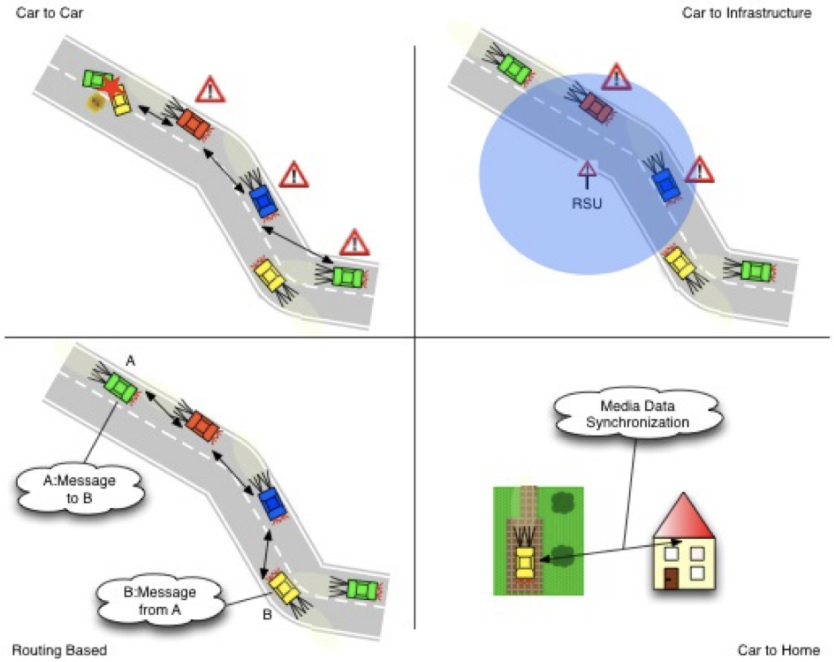

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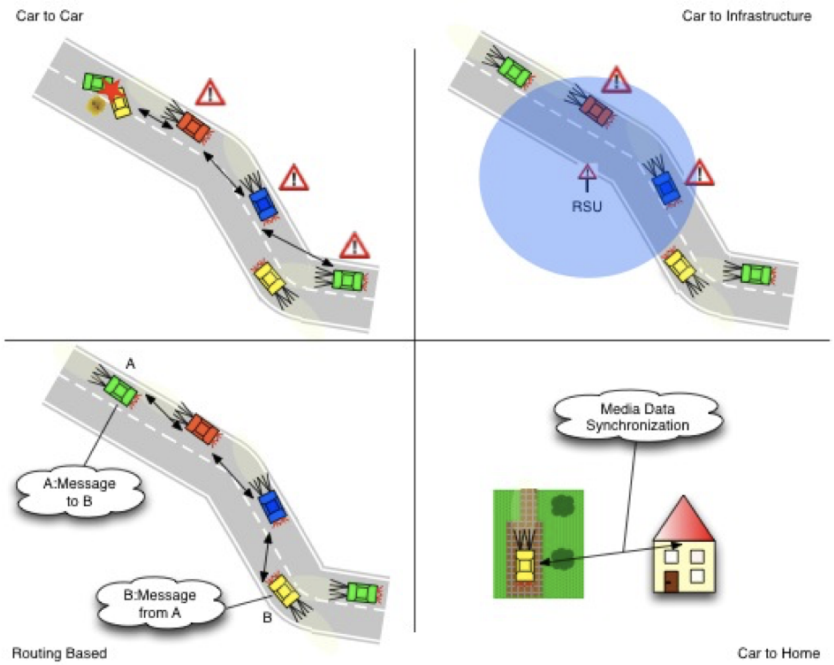

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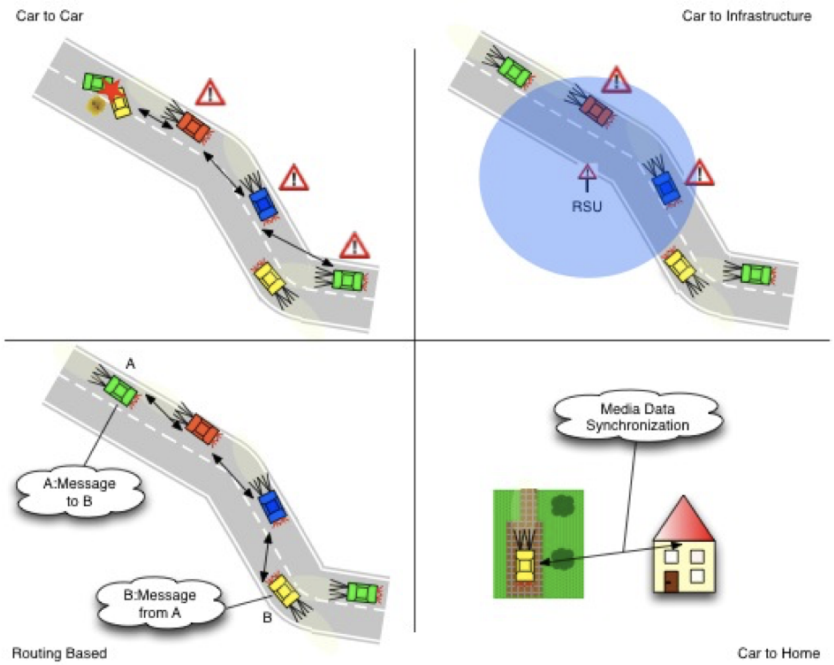

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Proposed approach

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- extended the gates refinement with a set of time constraints

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Let T_r be an attack tree, we defined an attack as as a mapping $\mathcal{A} : \mathcal{Q}_L \rightarrow (Act \times T) \cup \{Nil\}$ where

- $\mathcal{Q}_L$ is a set of leaf nodes
- Act is a set of attack actions
- T is a set of attack time

We say that $\mathcal{A}$ is a simple attack if $\mathcal{A}(l, t) \neq Nil$ only for one leaf node.

Time constraints

Let τ be a set of time constraints that is represented by a constant pair $< b, f >$, with b marking the start of an attack and f marking the (expected) end of attack on the parent node such that $b, f \in \mathbb{Q}$ and $b \leq f$.

A set of gates $\mathcal{G} : \{q_0\} \cup \mathcal{Q}_S \rightarrow \{AND, OR\} \times \tau$.

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Given an attack tree T_r, a set of attack time T, and a set of attack actions Act. An attack over T_r can only succeed;

Time constraints

- for *AND* node - if for all simple attacks $\mathcal{A}_1 \ldots \mathcal{A}_n$ such that $t_1 \ldots t_n$ are less than or equal to the constant time interval on the node,
- for *OR* node - if there exists a simple attack such that its attack time is less than or equal to the constant time interval on the node.

Timed automata

Attack trees via (weighted) timed automata

- Let T_r be an attack tree and τ be a set of time constraints, we proposed how to formally define some properties of the tree via weighted timed automata.

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- this properties can be checked and verified using *UPPAAL*.
- We translated the tree into a parallel composition of weighted timed automata (WTA).

UPPAAL translation

- The sets of nodes of the attack trees are translated to a set of locations in the weighted timed automata.
- For each leaf node in the attack tree, we have a WTA that represents a linear path from the leaf to the root node.
- Altogether there are as many WTAs as the leaf nodes in the attack tree. Each location that represents a leaf which has a clock that is activated when there is an attack in the corresponding leaf in the tree.
- An attack on a node in the tree represents an enabled transition in the WTA. Initially, clocks become active when events synchronized, and end with either a success or fail synchronization action.

UPPAAL analysis

- If a location that represent a the sub_goal of the attack tree has an *OR* gate, a single event (i.e. action) together with a clock is activated and a transition to the target location is enabled
- otherwise all the events (i.e., *AND* gate) needs to be activated, and the target location can only be reached if all elapsing time in the clocks is less than (predefined) *max* (that represent the constant time intervals).

Discussion and future work

- We discussed how attack trees can be extended with a set of attack time, and a set of time constraints at the gates refinement
- we show how this extensions can be modelled and analyse using WTA
- We plan to study how actions observations, which cannot be identified as vulnerabilities with attack trees can be prevented from aiding an attack.

Thank you!