RT-205: Identifying and Measuring Modularity Violations

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Research Task / Overview

- Cyber-physical systems are composed of diverse subsystems consisting of both physical and software components developed by different vendors.

- Stakeholders, such as DoD, have increasingly emphasized modular and open approaches to system development to improve interoperability, facilitate system evolution and technology insertion, and foster competition.

- With the advance of technology, the recognition of new consumer needs, and the detection of deficiencies in the current systems, can upgrades, replacements, or problem fixes happen quickly in a plug-and-play manner? In other words, is a cyber-physical system truly modular?
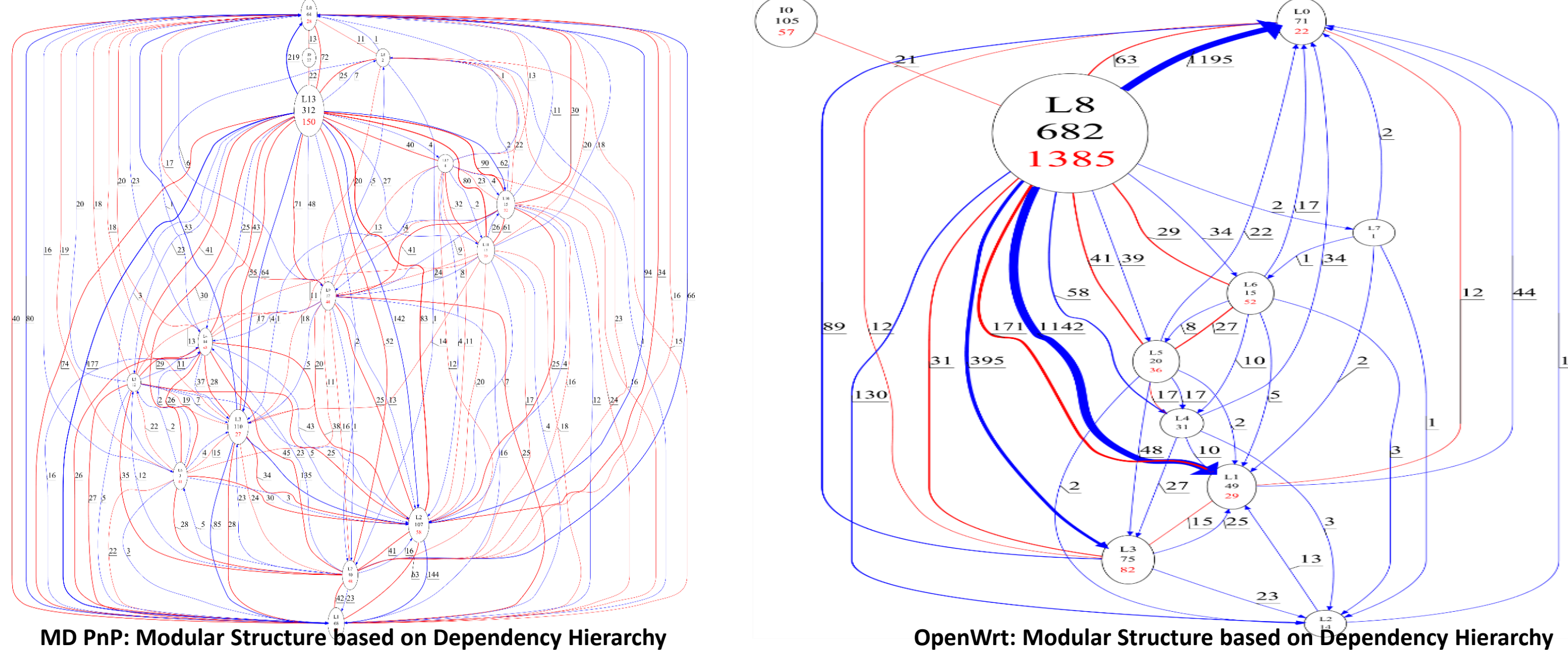
Data & Analysis

OpenWrt: A Linux operating system targeting embedded devices.

MdPnP: The medical device "Plug-and-Play" interoperability program advancing safe and secure interoperability to improve patient care.
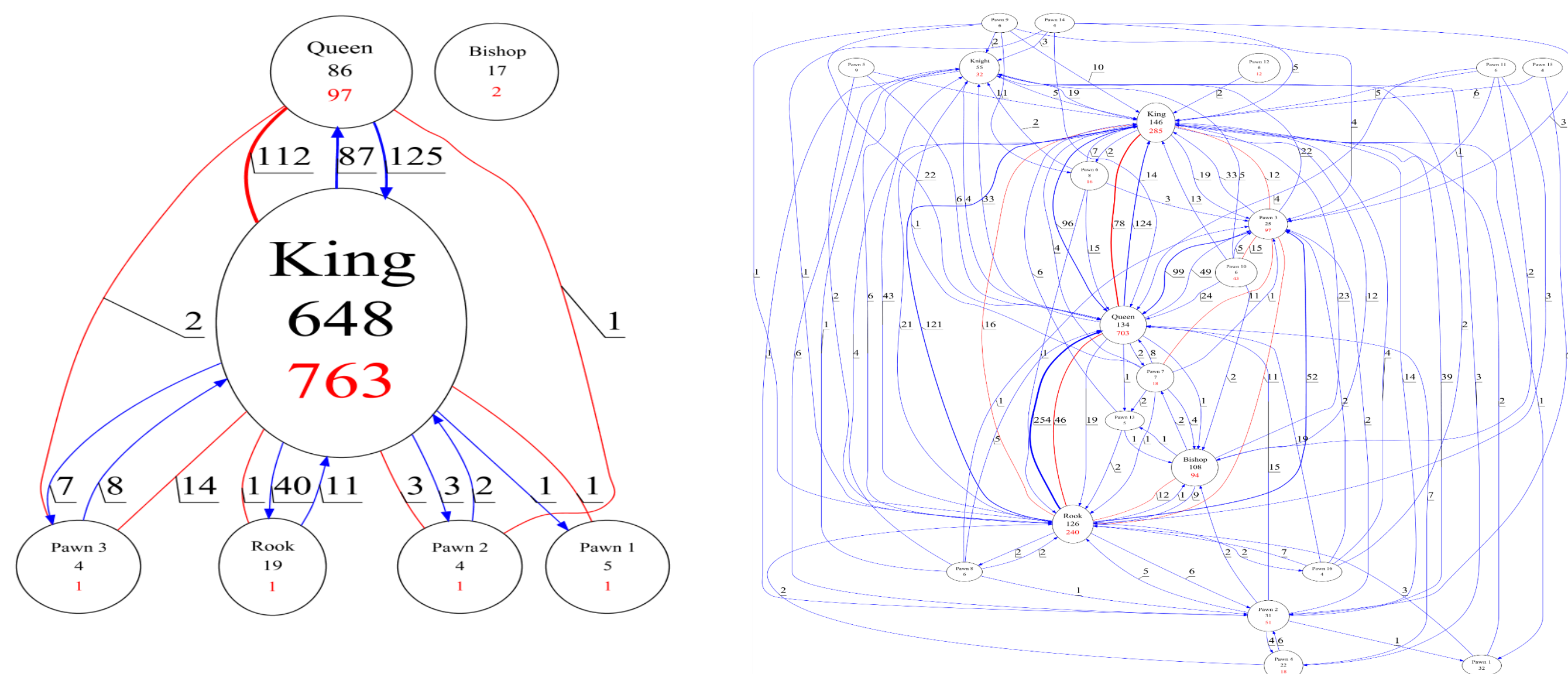
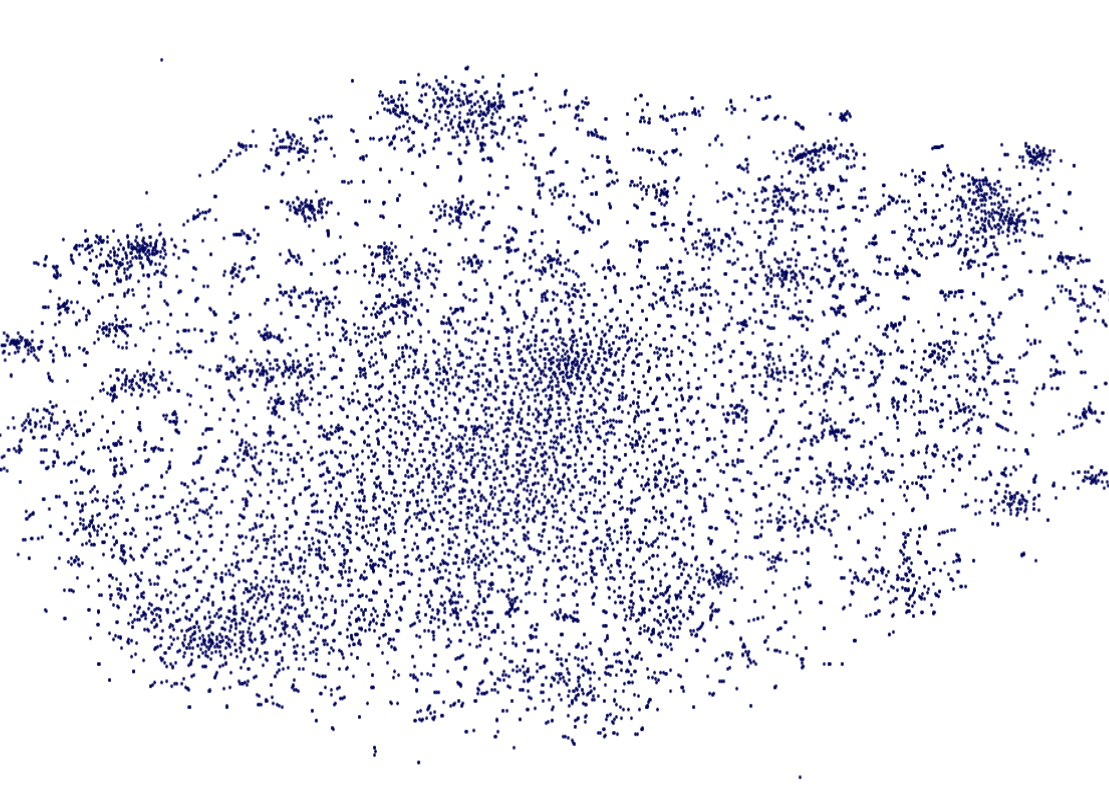1. Root Package View (a.k.a. the development view).

MD PnP: Root Package   OpenWrt: Root Package
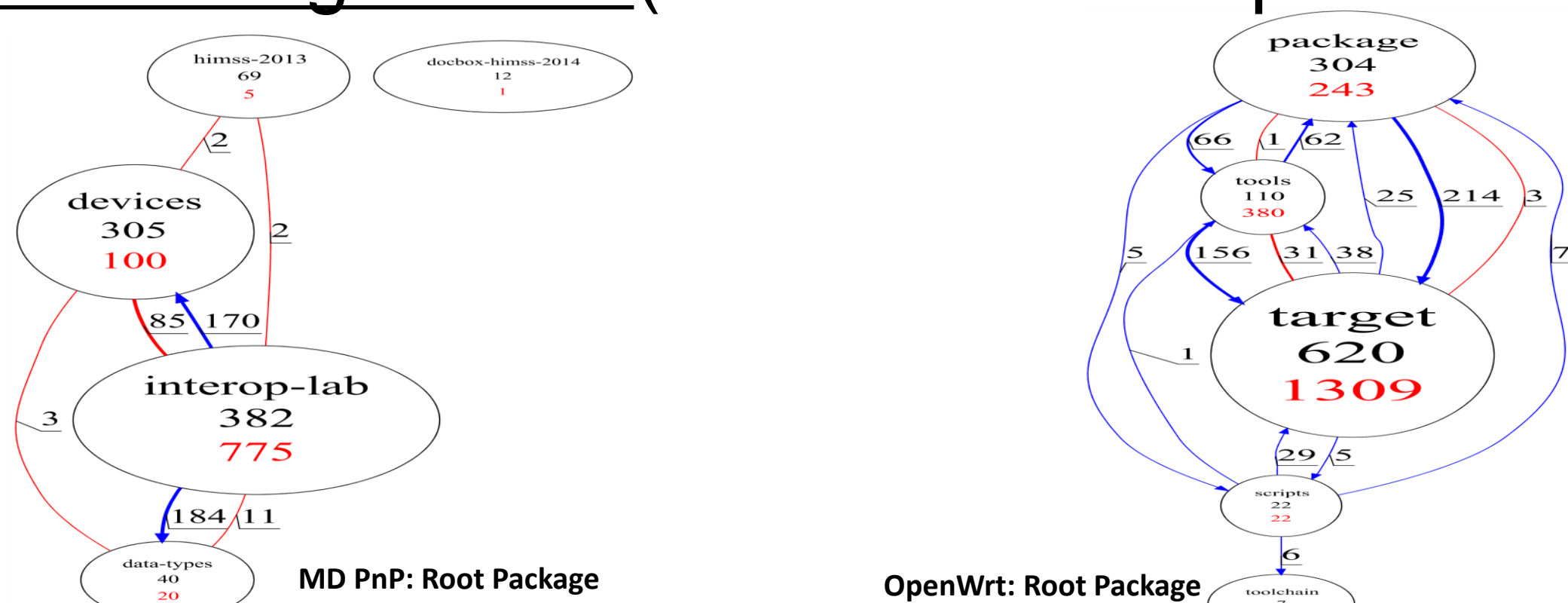
2. Dependency Hierarchy (Sequential Task Allocation)

MD PnP: Modular Structure based on Dependency Hierarchy   OpenWrt: Modular Structure based on Dependency Hierarchy

3. Organizational Modular Structure

4. Conceptual Structure

t-SNE plot of a word2vec model trained on OpenWRT project documentation

2	3	4	5	6	7
linux	image	file	package	add	patch
target	support	default	openwrt	fix	es-3
generic	device	use	makefile	update	es-4
es-2	board	user	config	build	-default
ar71xx	usb	data	network	remove	pending-4
ramips	driver	option	base-files	version	international
brcm63xx	profiles	configuration	etc	make	submitting
lantiq	platform	interface	src	change	alike
brcm2708	switch	http	lib	documentation	pagesource
adm5120	ethernet	server	control	upgrade	attribution-share
brcm47xx	wifi	set	ipkg	content	lzma-loader
mtd	phy	port	net	lede	backport-4
ath79	code	rule	modules	page	coldfire
ixp4xx	register	using	services	missing	map
ipq806x	gpio	start	init	new	uml
s3c24xx	wireless	address	scripts	enable	

Conceptual clusters from OpenWRT mapped to the Root Package view

Goals & Objectives

- Examine the Criteria to Decompose a CPS into Modules

- Build a "Domain Concept Learner" to Identify Modularity Violations in Different Domains

- Build Decision Framework and Demonstrator
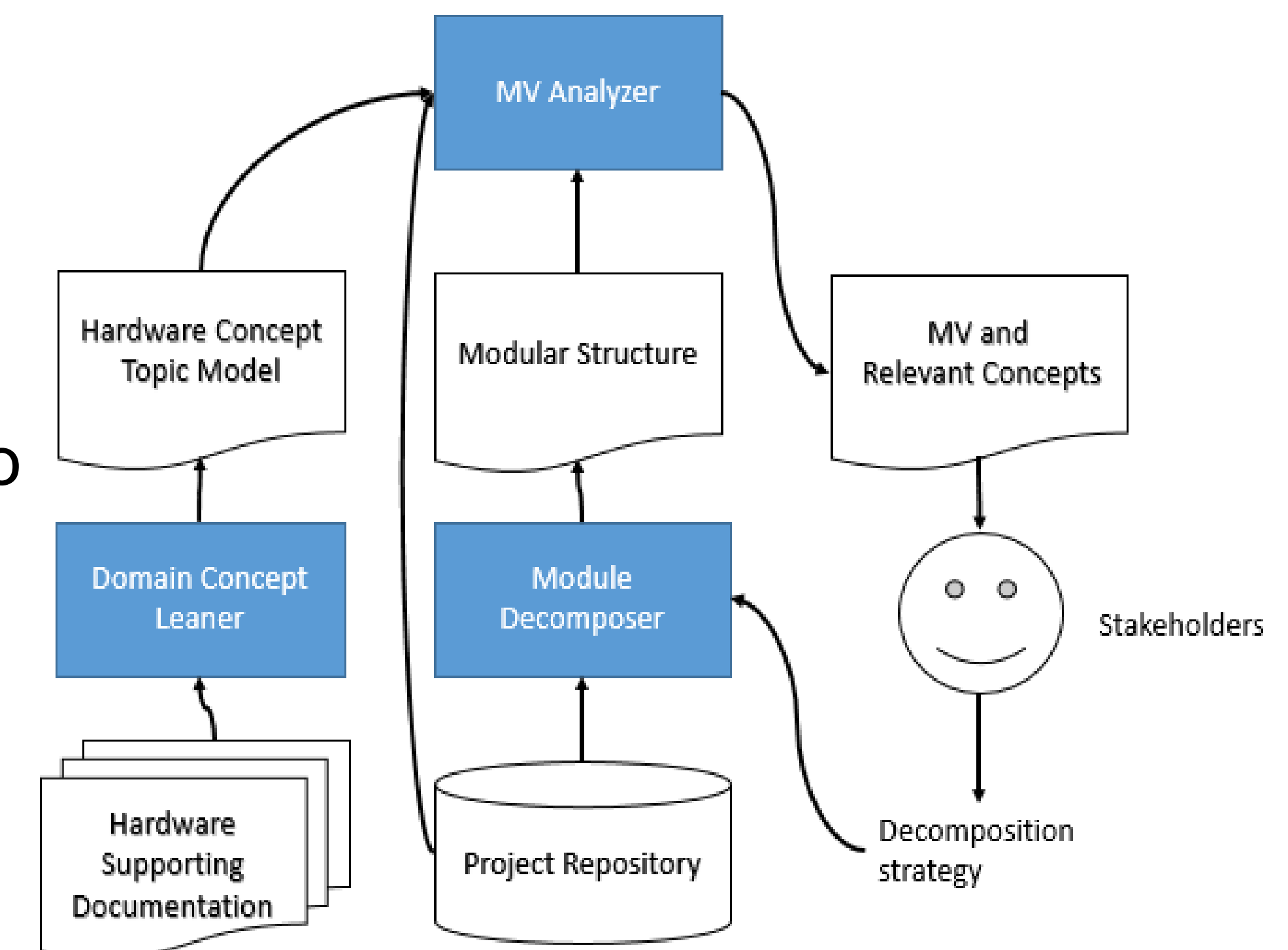
Methodology

1. Examine the Criteria to Decompose a CPS into Modules

    ☐ Use three different criteria to decompose a large-scale, complex system into modules to represent different stakeholders concerns:
    - Package decomposition
    - Dependency hierarchy decomposition
    - Organizational structure decomposition

    ☐ Investigate two different dimensions of relationship among modules:
    - The static structural dependencies
    - The co-change relationship

2. Build a "Domain Concept Learner" to Identify Modularity Violations in Different Domains

    - Use natural language processing (NLP) techniques to analyze project documentation and organize keywords into topics
    - Extract hardware related terms for use in co-change analysis
    - Identify relationships among topic groups to extract a semantic structure for the project

Future Research

☐ Short-term:
- Cross reference learned domain concepts to modules.
- Identify and measure modularity violations at different levels of decomposition for different stakeholders.
- Build proof-of-concept demonstrator.

☐ Long-term:
- Prioritize and visualize modularity violations for restructuring decision-making for stakeholders.
- Provide in-depth interpretation of the root causes of modularity violations for restructuring insights.

Contacts/References

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