Mobile Matrix

A Multihop Address Allocation and Any-To-Any Routing in Mobile 6LoWPAN

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Agenda

1. Introduction and Motivation
2. Design Overview
3. Handling Mobility
4. Complexity Analysis
5. Experiments
6. Related Works
7. Conclusions and Future Work

1.

Introduction and Motivation

Routing under mobility scenario

Introduction and Motivation

- Mobility is a major factor present in everyday life
  - It makes life easier and applications more flexible
  - IoT can benefit from it
- <u>Routing</u> and <u>addressing</u> standards for low-power devices (RPL, CTP, 6LoWPAN/IPv6)
  - They do not handle **<u>mobility</u>**
- Routing under mobility scenario trade-offs
  - Memory
  - Control messages
  - Routing rules complexity

Introduction and Motivation

- Mobile Matrix (μMatrix)
  - Routing protocol for 6LoWPAN
    - Any-to-any routing enabled
  - It uses hierarchical address allocation
    - It enhances memory resource usage
  - Node Mobility Management
    - Nodes do not ever change its IPv6 address

Mobile Matrix (µMatrix)

1. Low routing memory footprint

2. Adjustable control message overhead

3. Routing under mobility without changing nodes IPv6 Address

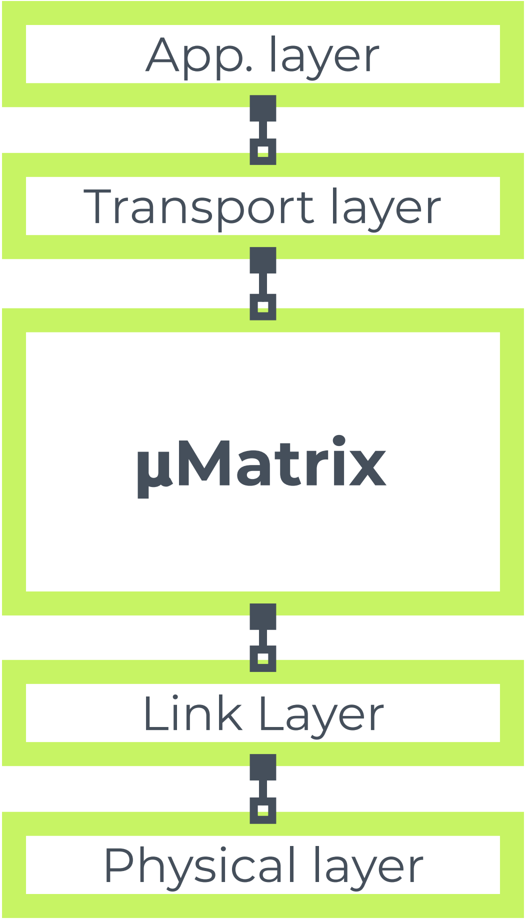
2.

Design overview

1. Architecture
2. Hierarchical Address allocation
3. Mobility management

Design Overview

µMatrix Architecture



Design Overview

µMatrix Architecture

Data Plane **Control Plane**

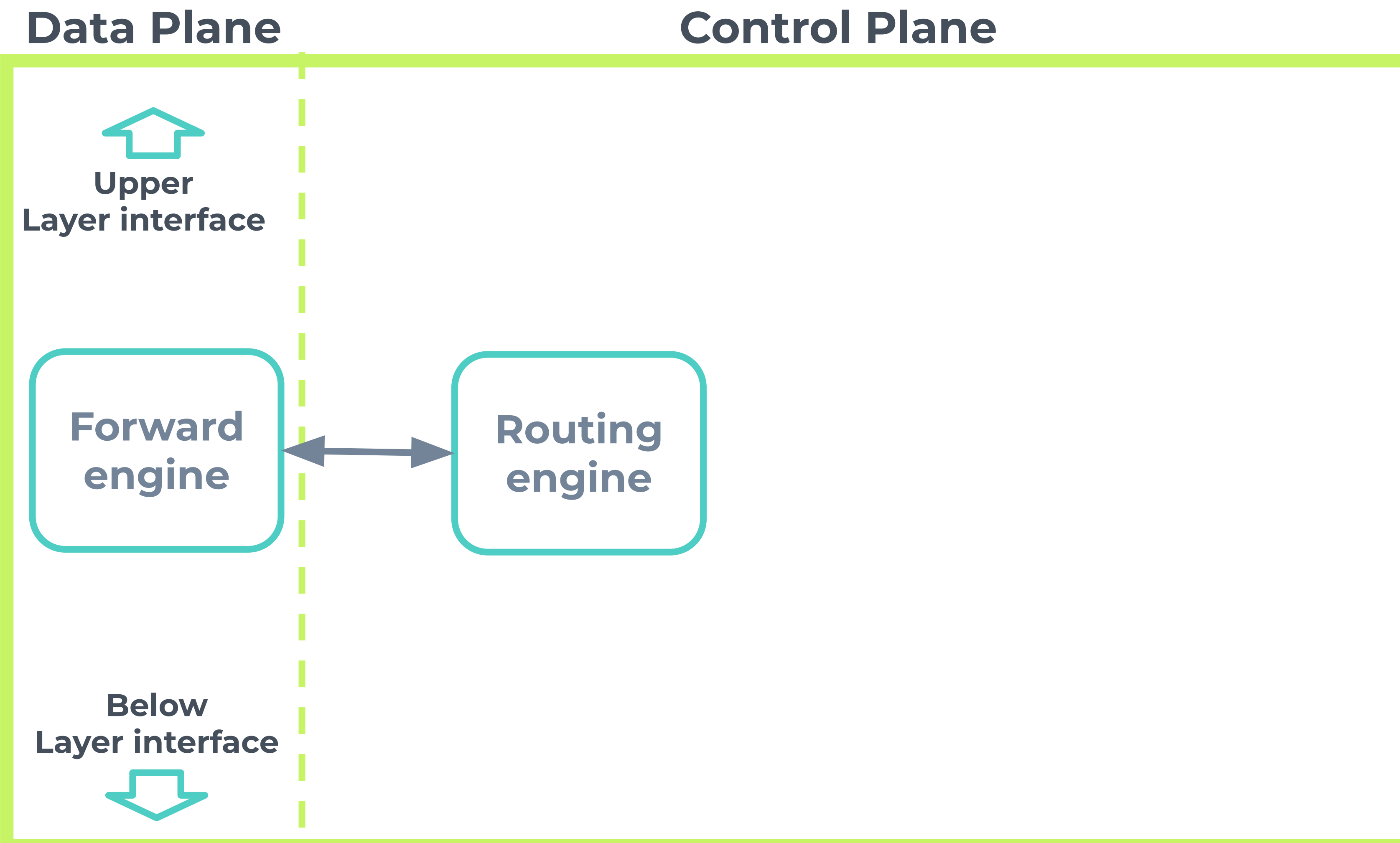
Design Overview

µMatrix Architecture

Data Plane **Control Plane**

Design Overview

µMatrix Architecture



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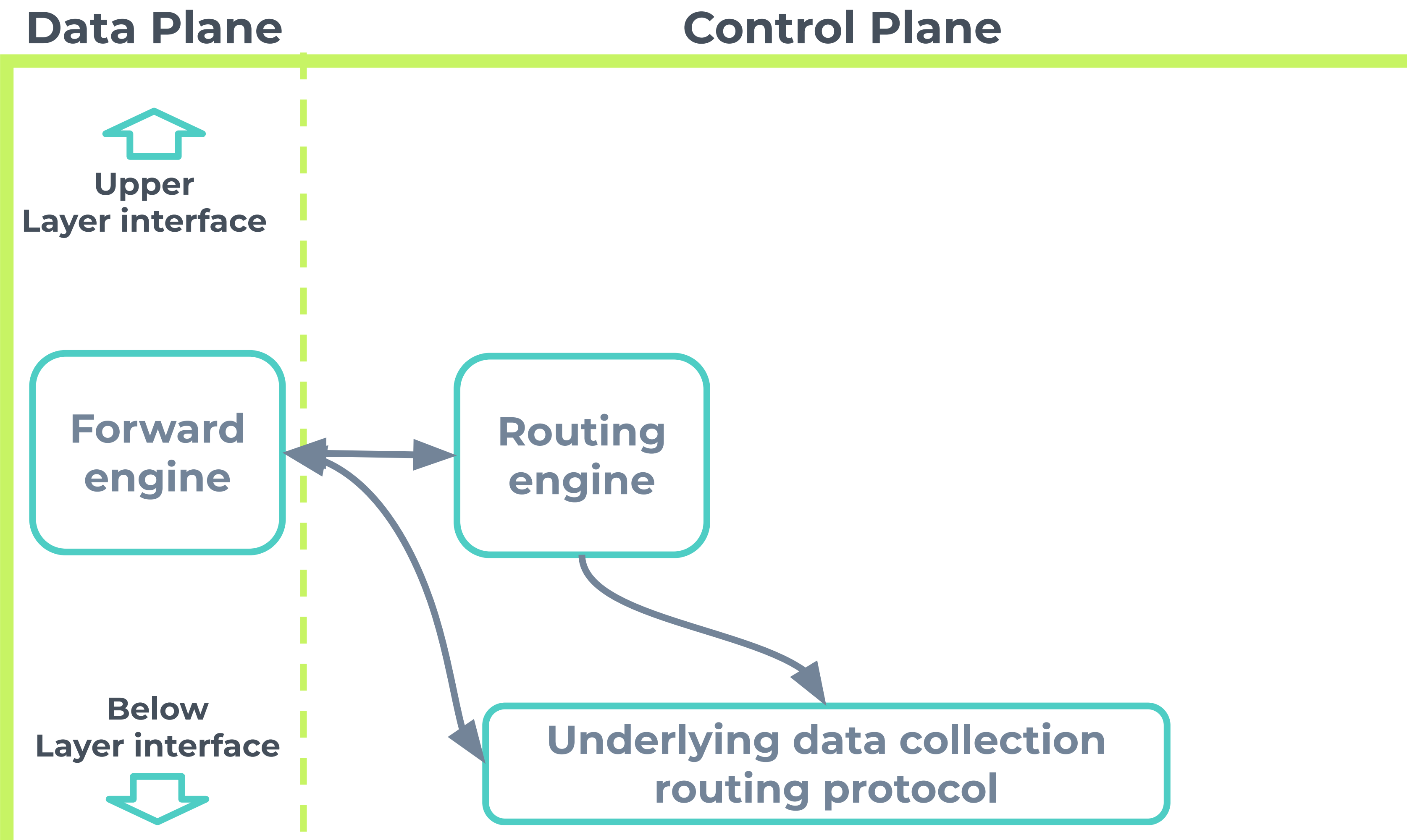
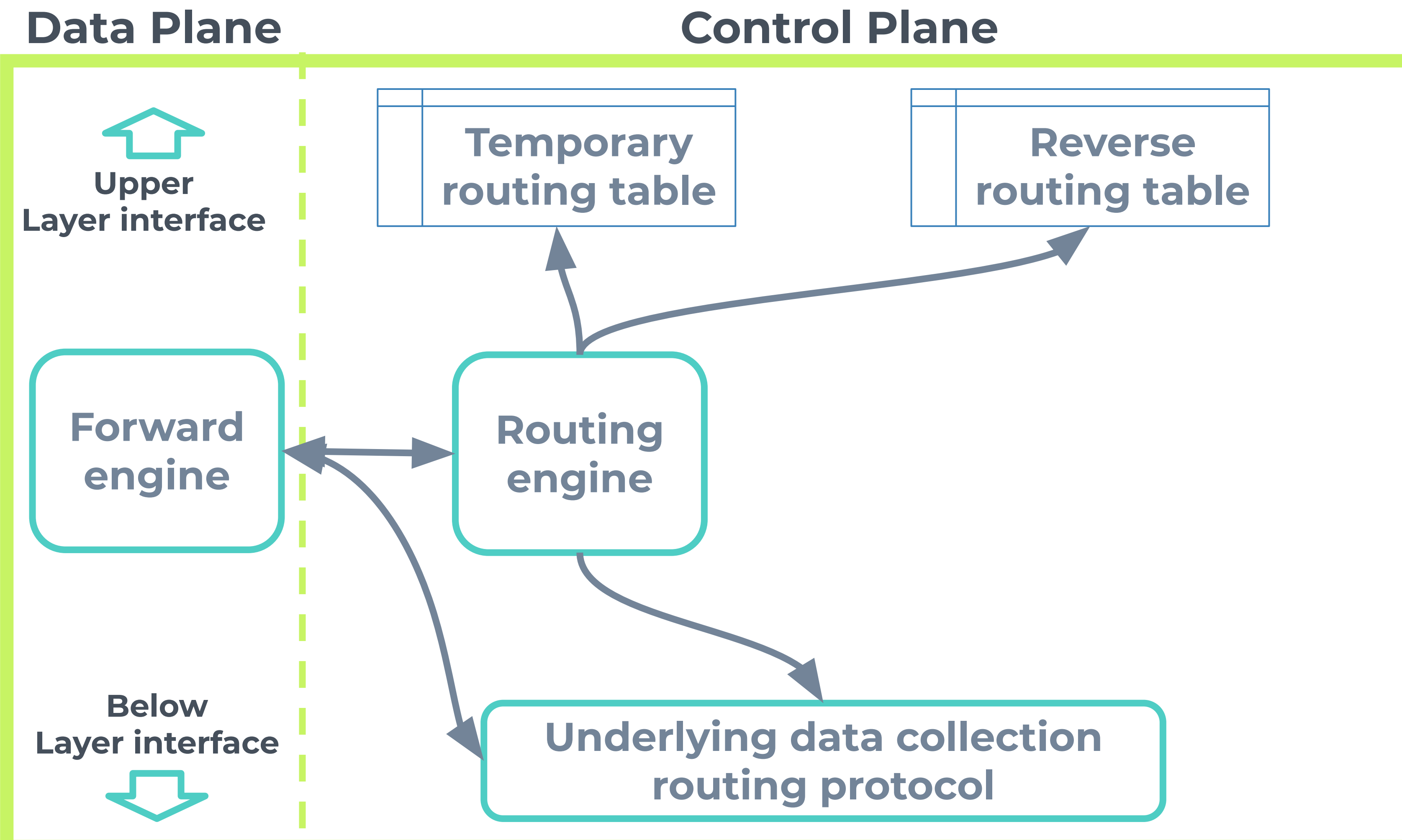
µMatrix Architecture



Design Overview

µMatrix Architecture



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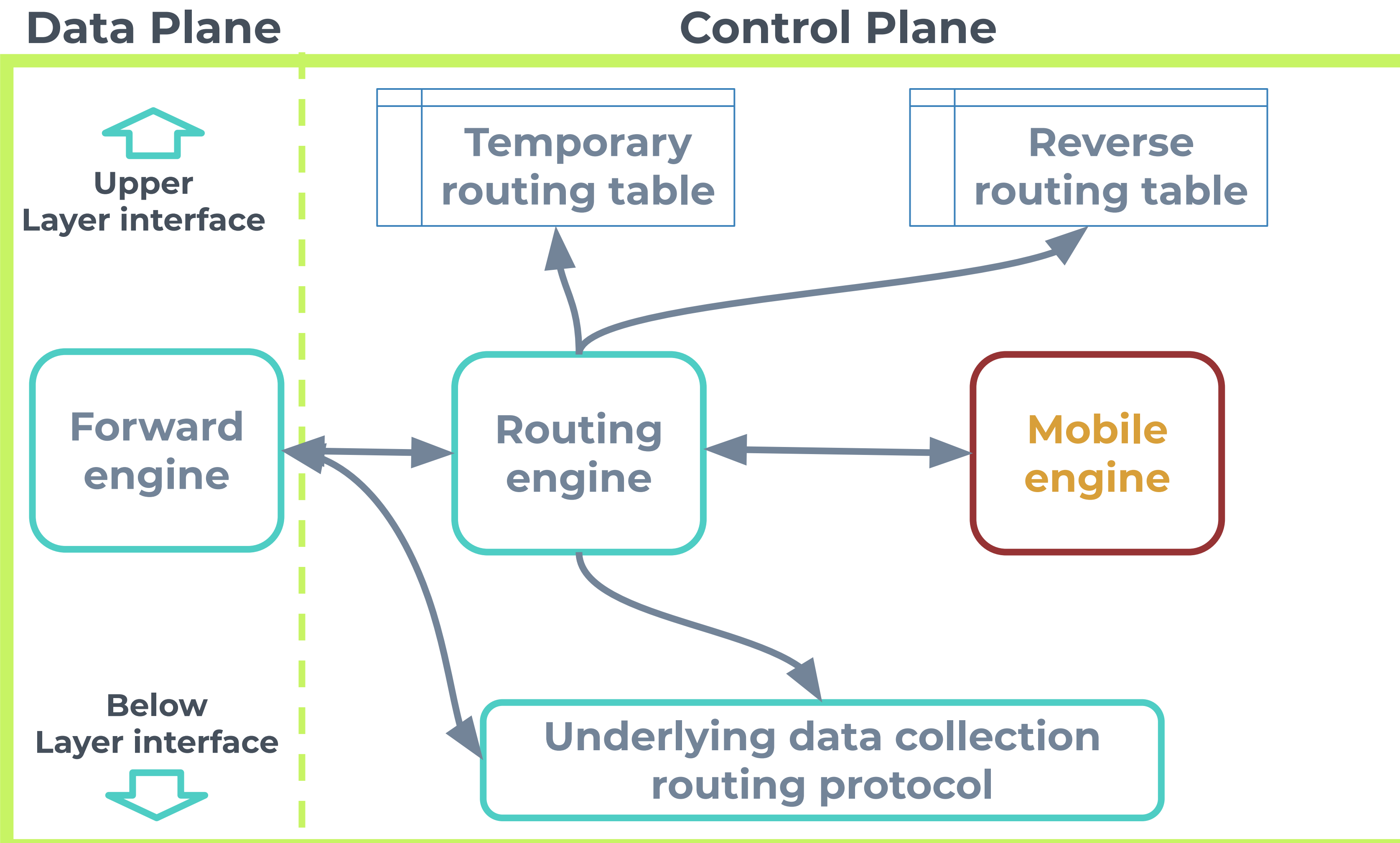
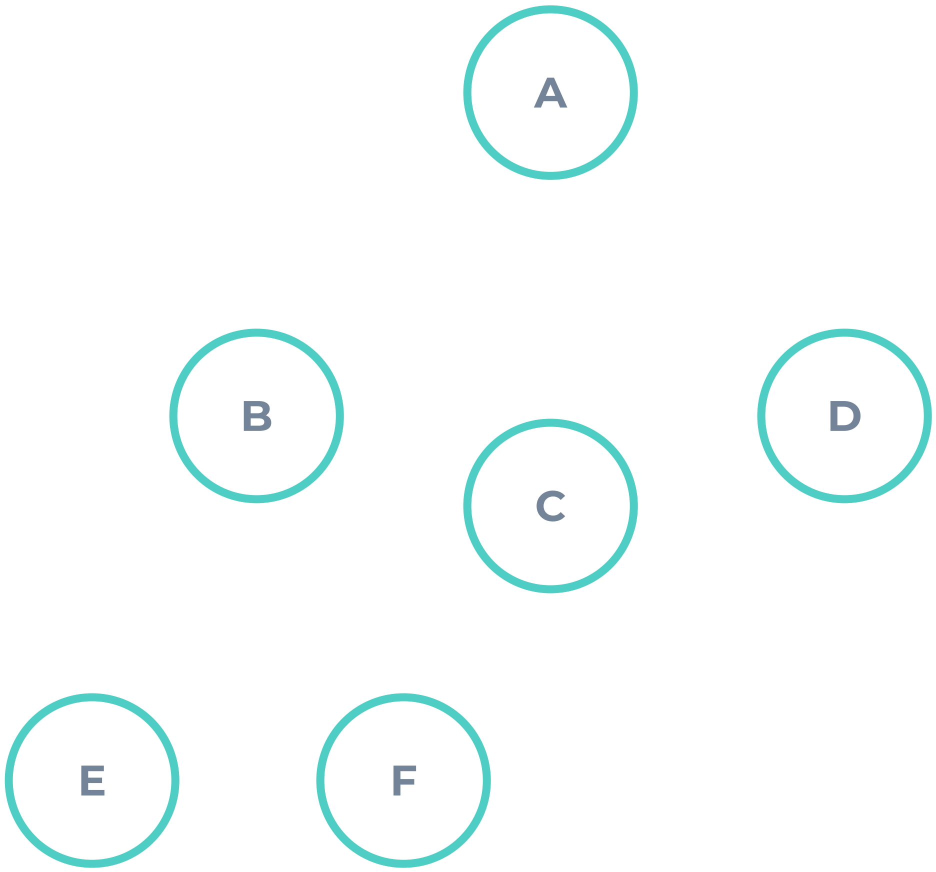
µMatrix Architecture



Design Overview

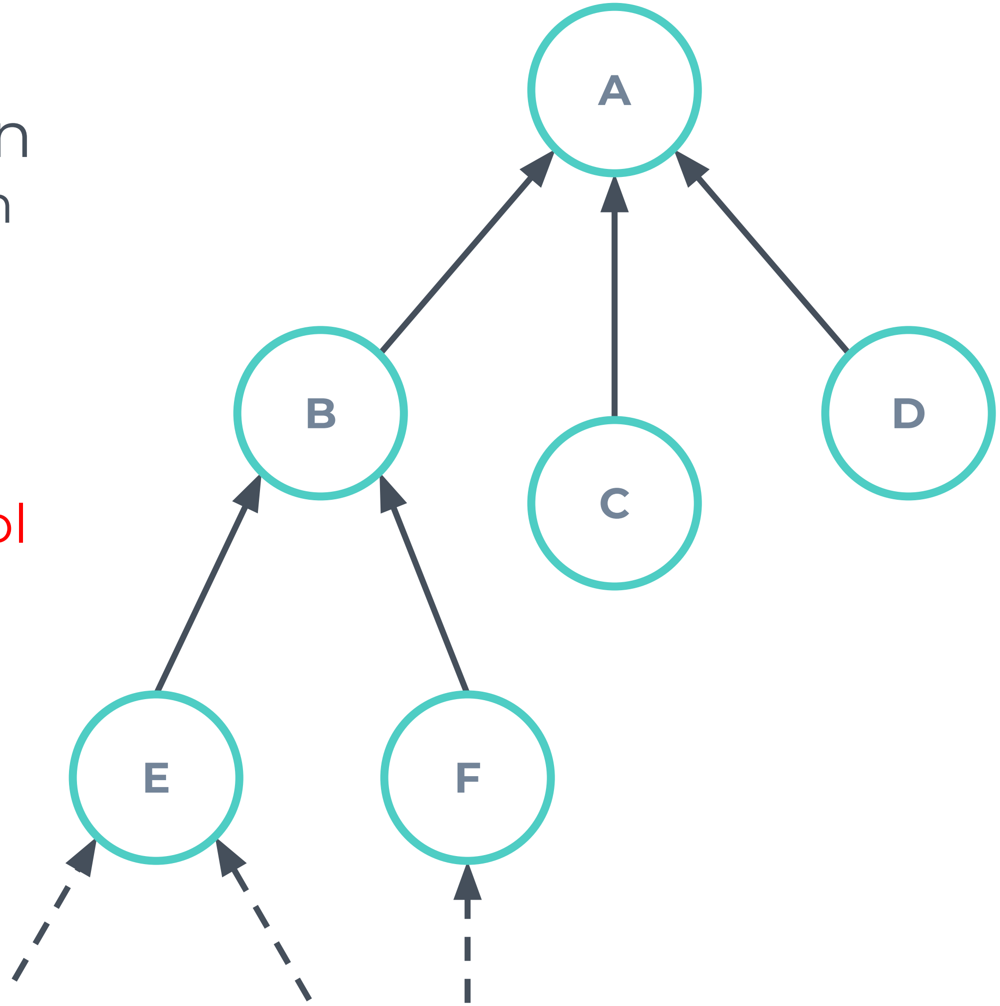
µMatrix Hierarchical Address allocation



Design Overview

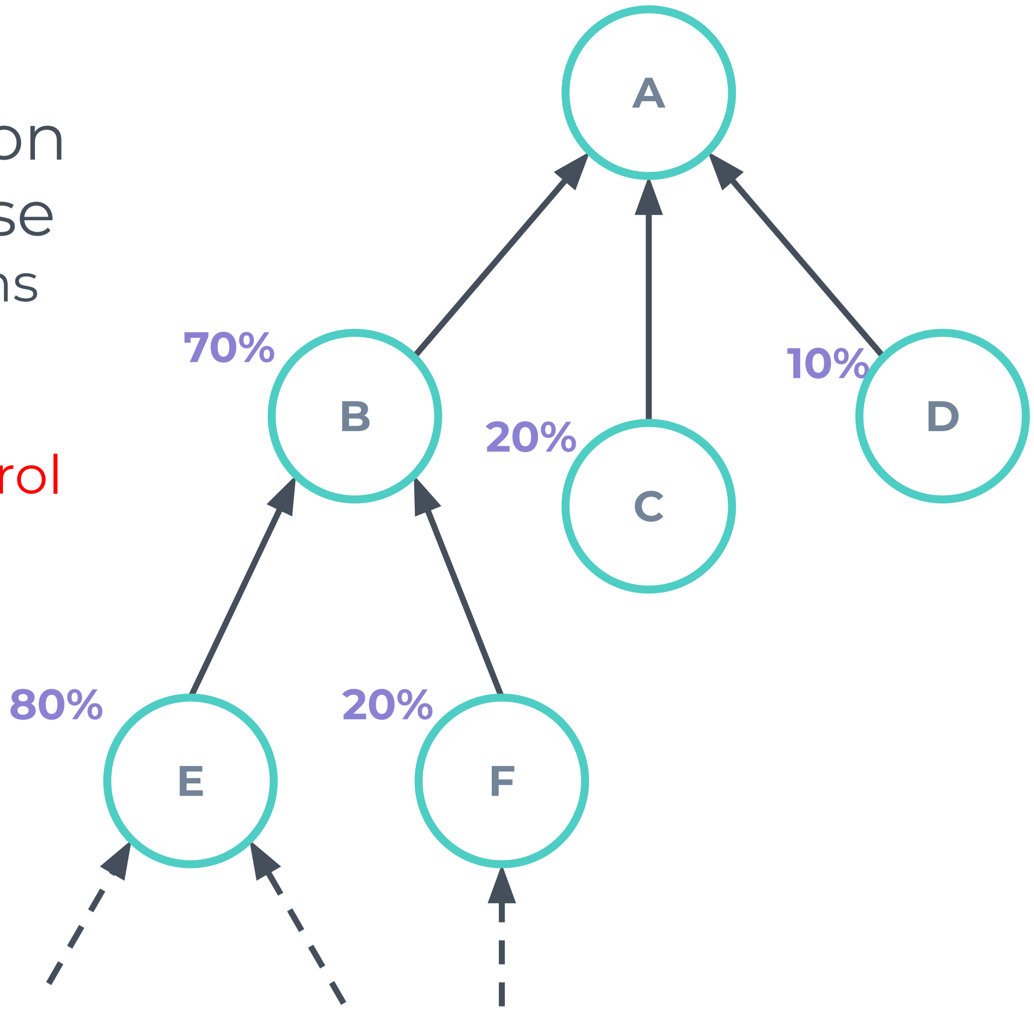
µMatrix Hierarchical Address allocation

1. Tree data collection
   a. μMatrix relies on an underlying data collection routing protocol
      i. Ex: RPL or CTP
   b. It takes O(n) control messages



µMatrix Hierarchical Address allocation

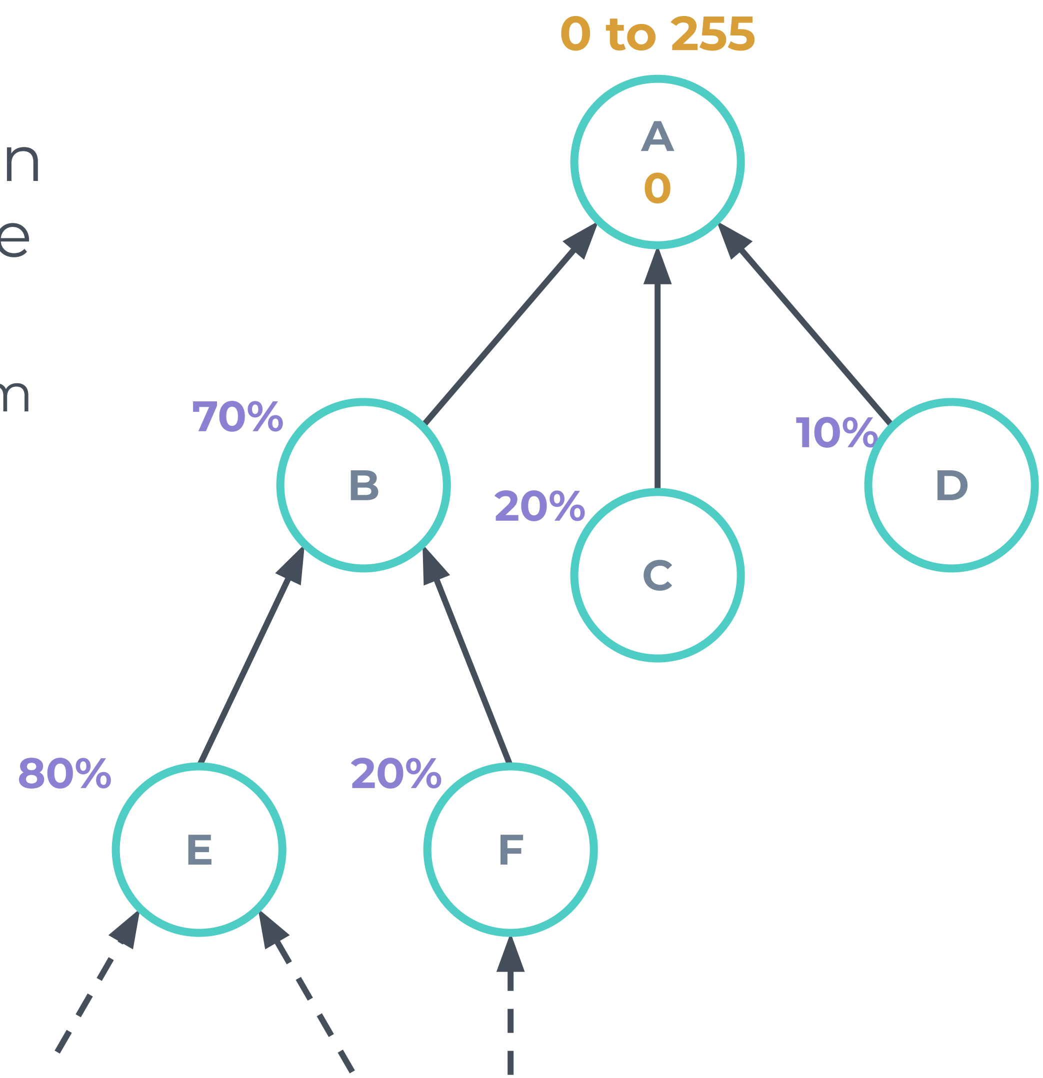
1. Tree data collection
2. Aggregation phase
   a. Each node informs the number of children
   b. It takes O(n) control messages



Design Overview

µMatrix Hierarchical Address allocation

1. Tree data collection
2. Aggregation phase
3. Address allocation
    a. Node receives from parent a range of available IPs proportionally
    b. Nodes take one IP



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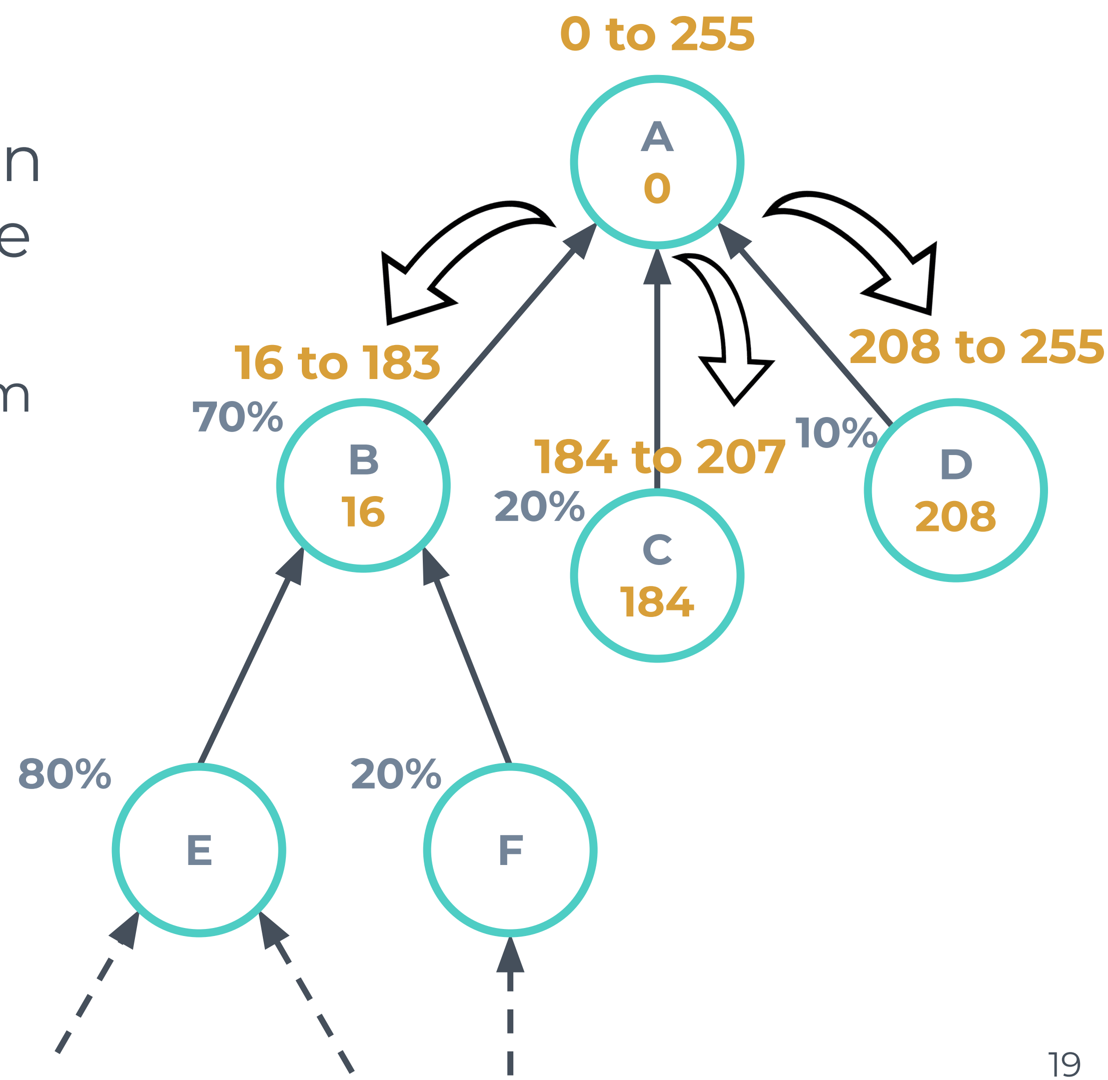
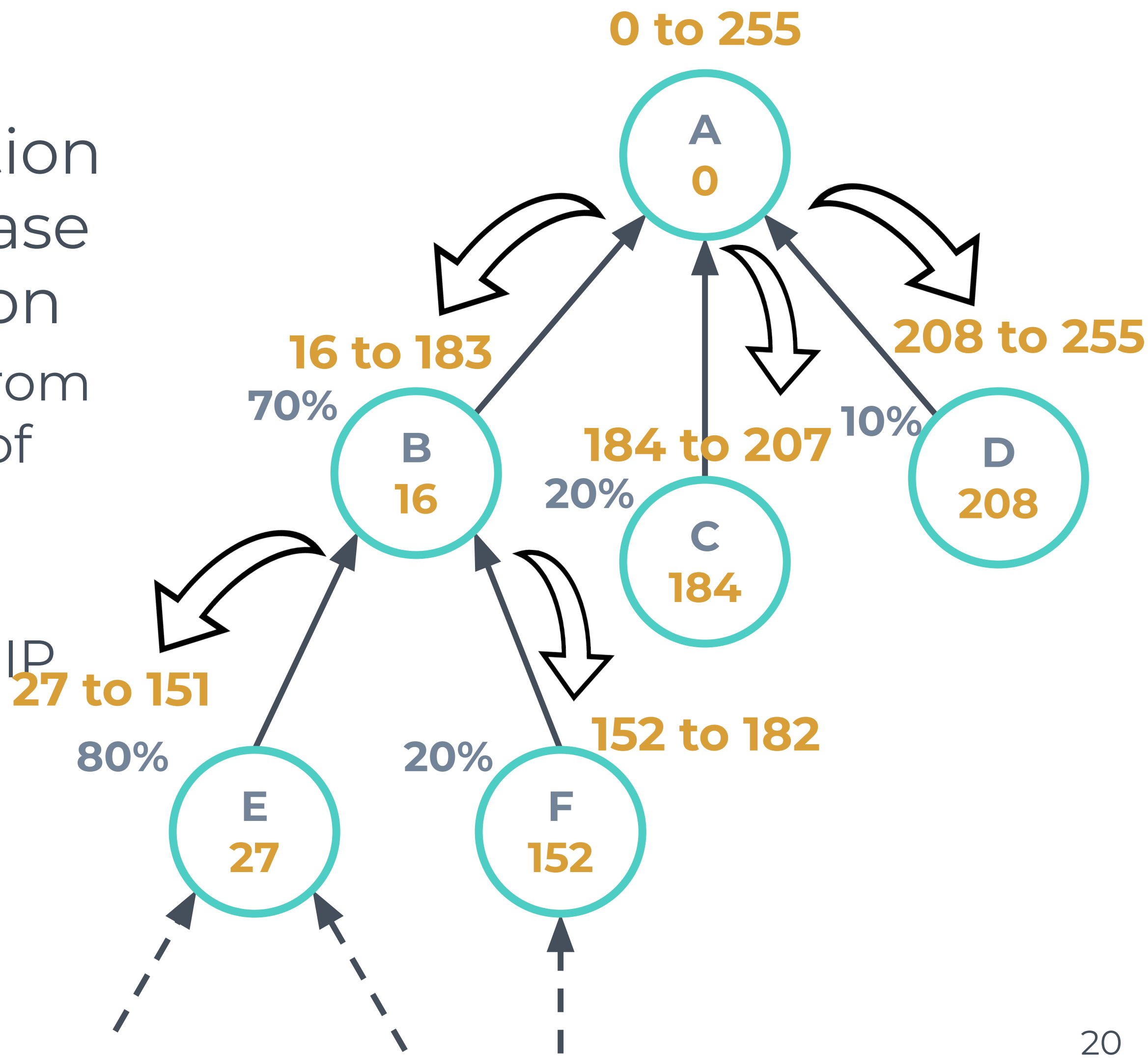


Design Overview

µMatrix Hierarchical Address allocation

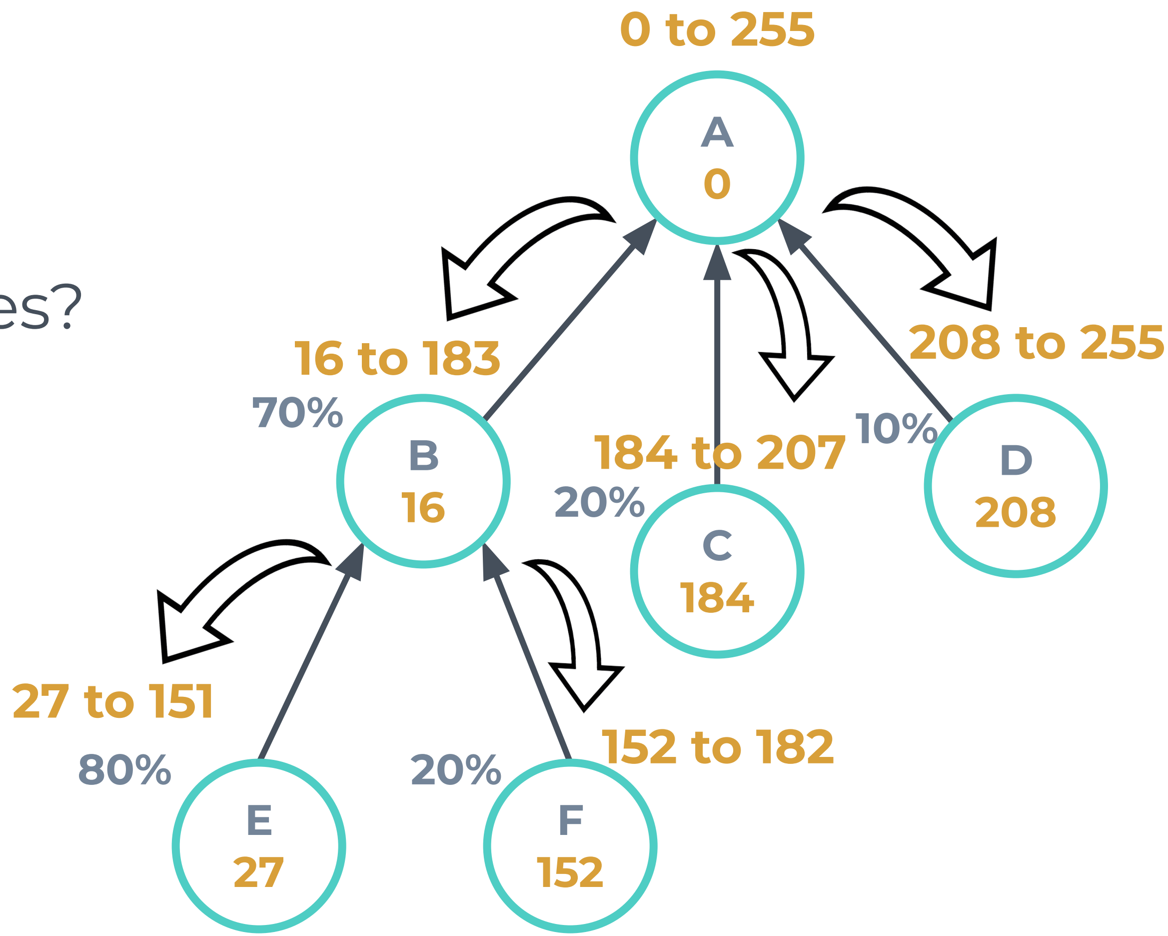
1. Tree data collection
2. Aggregation phase
3. Address allocation
   a. Node receives from parent a range of available IPs proportionally
   b. Nodes take one IP
   c. Recursively distribute the remaining IPs



Design Overview

µMatrix Mobility management

1. What to do if B moves and the topology changes?



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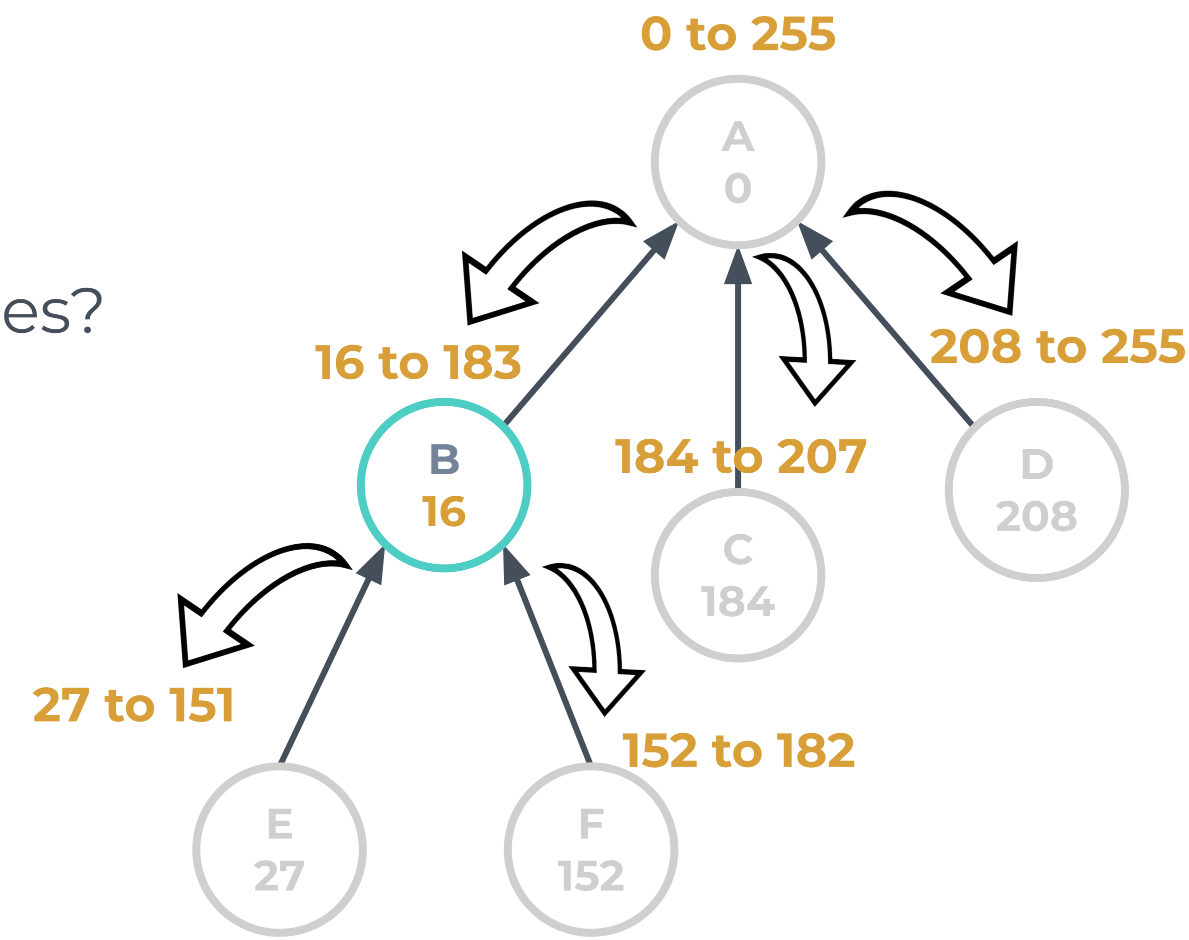

Design Overview

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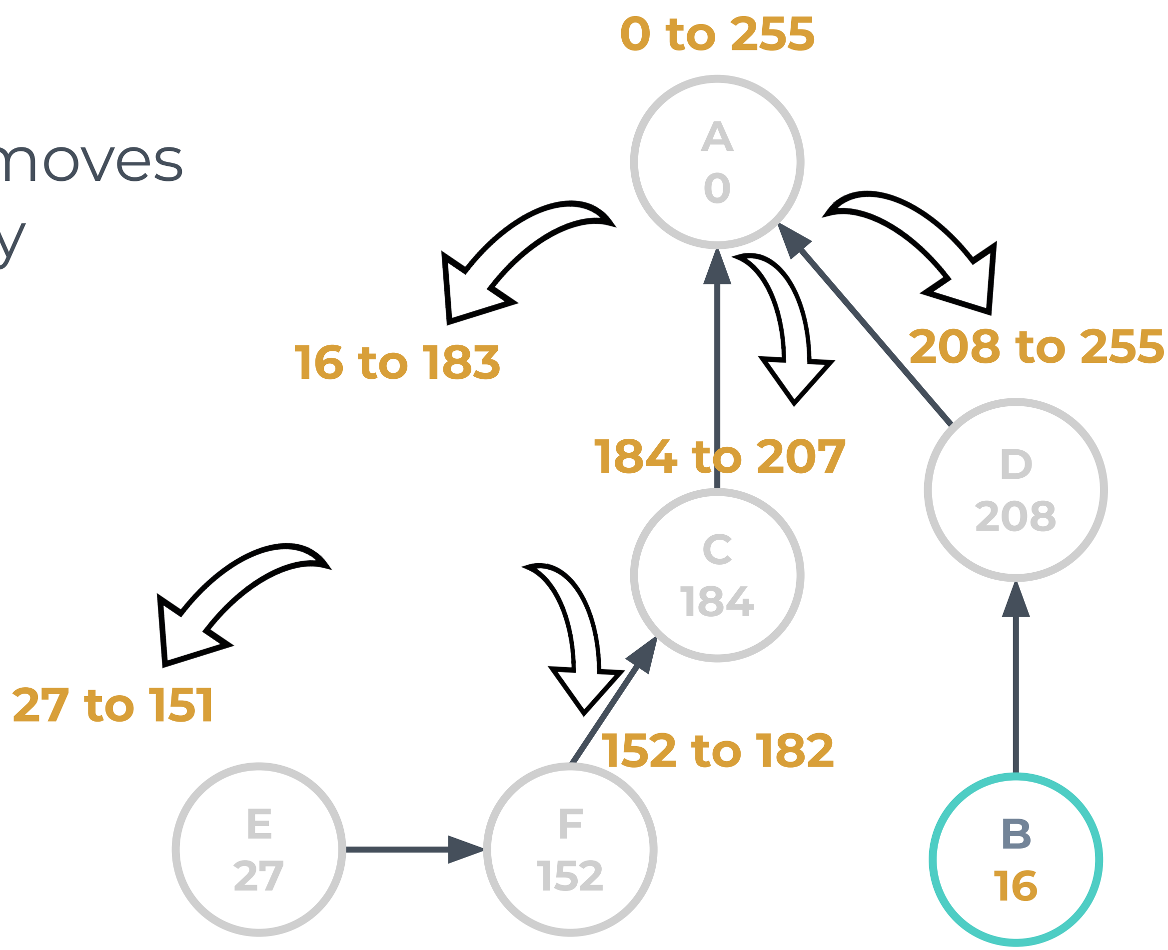
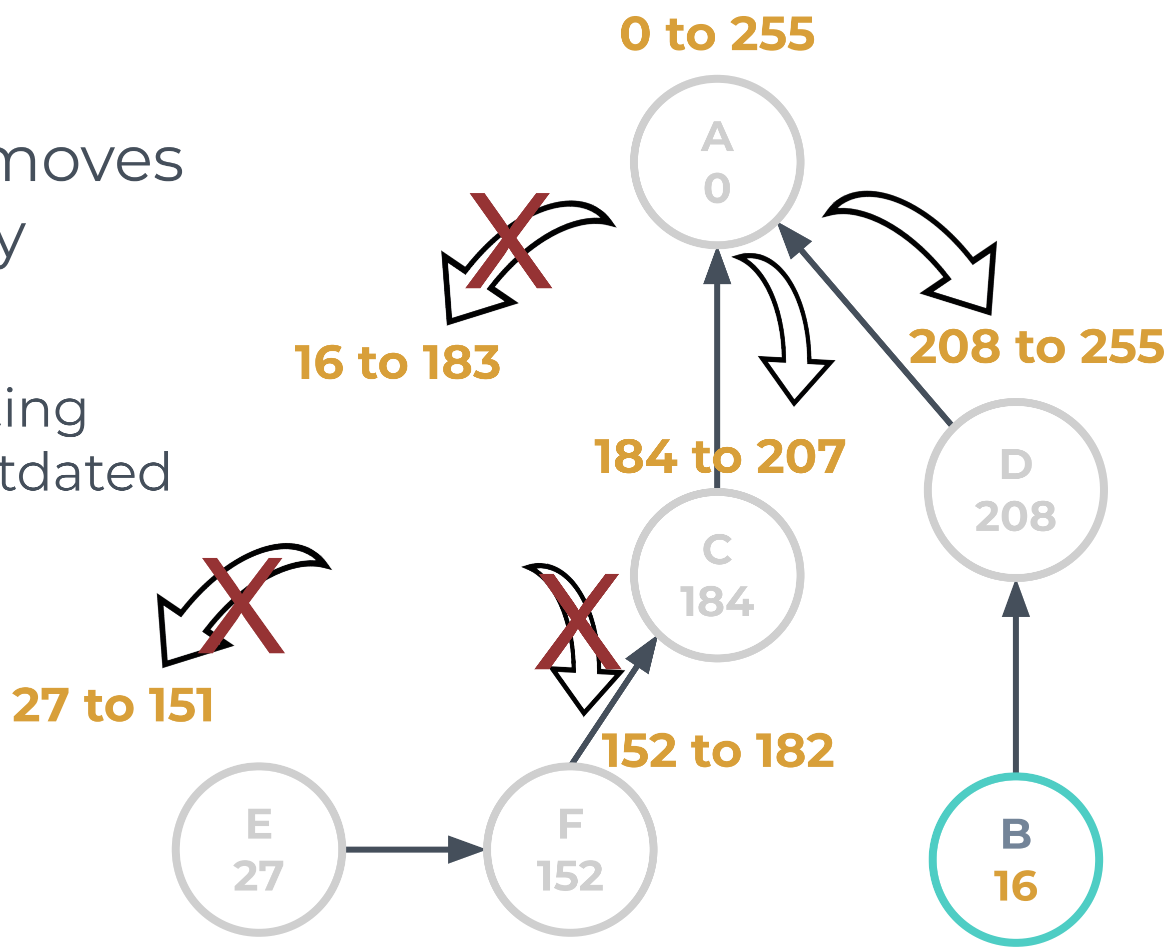


Design Overview

µMatrix Mobility management

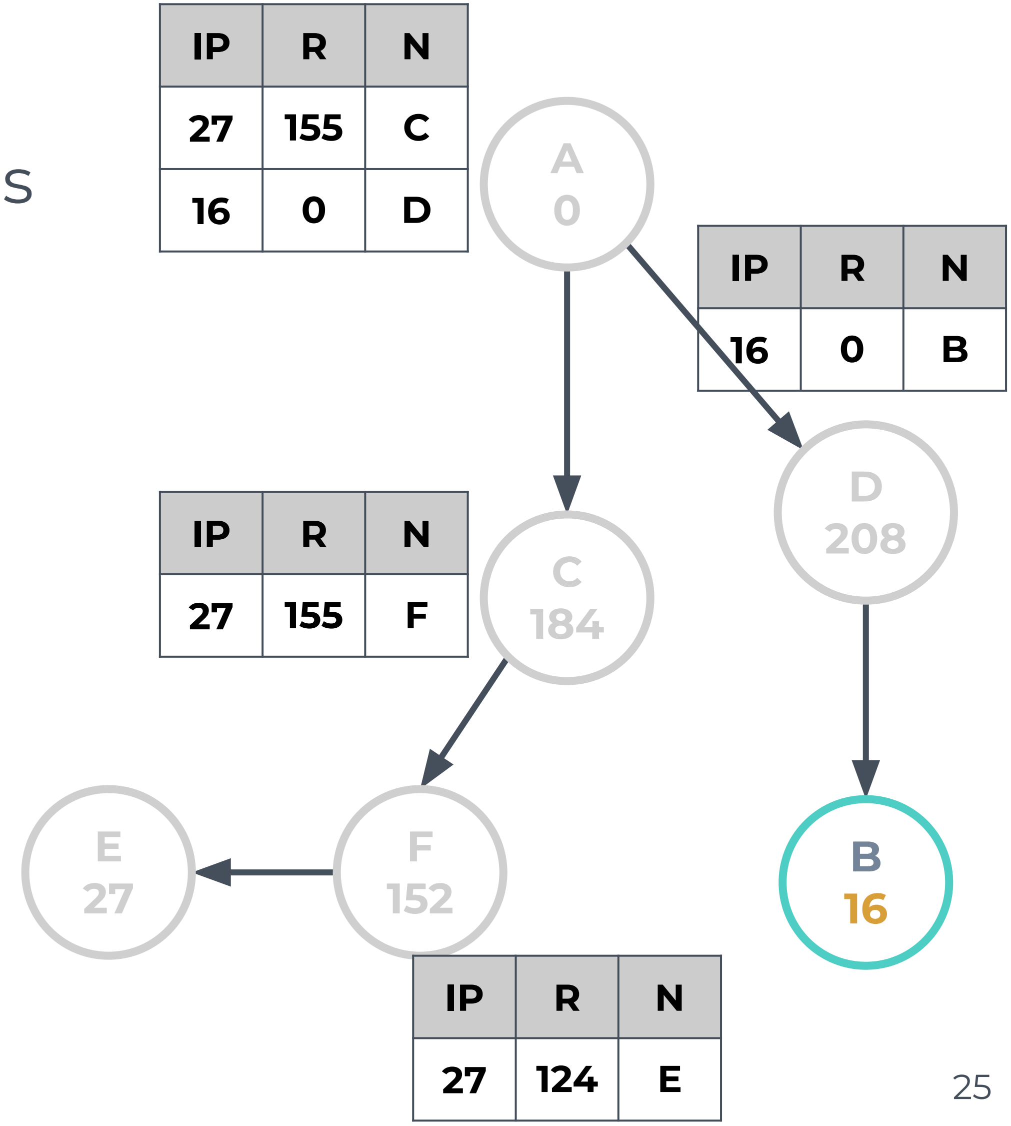
1. What to do if B moves and the topology changes?
   a. The reverse routing tree become outdated



Design Overview

µMatrix Mobility management

1. What to do if B moves and the topology changes?
   - ***µ*Matrix Mobile engine redo the paths**



IP	R	N
27	155	C
16	0	D

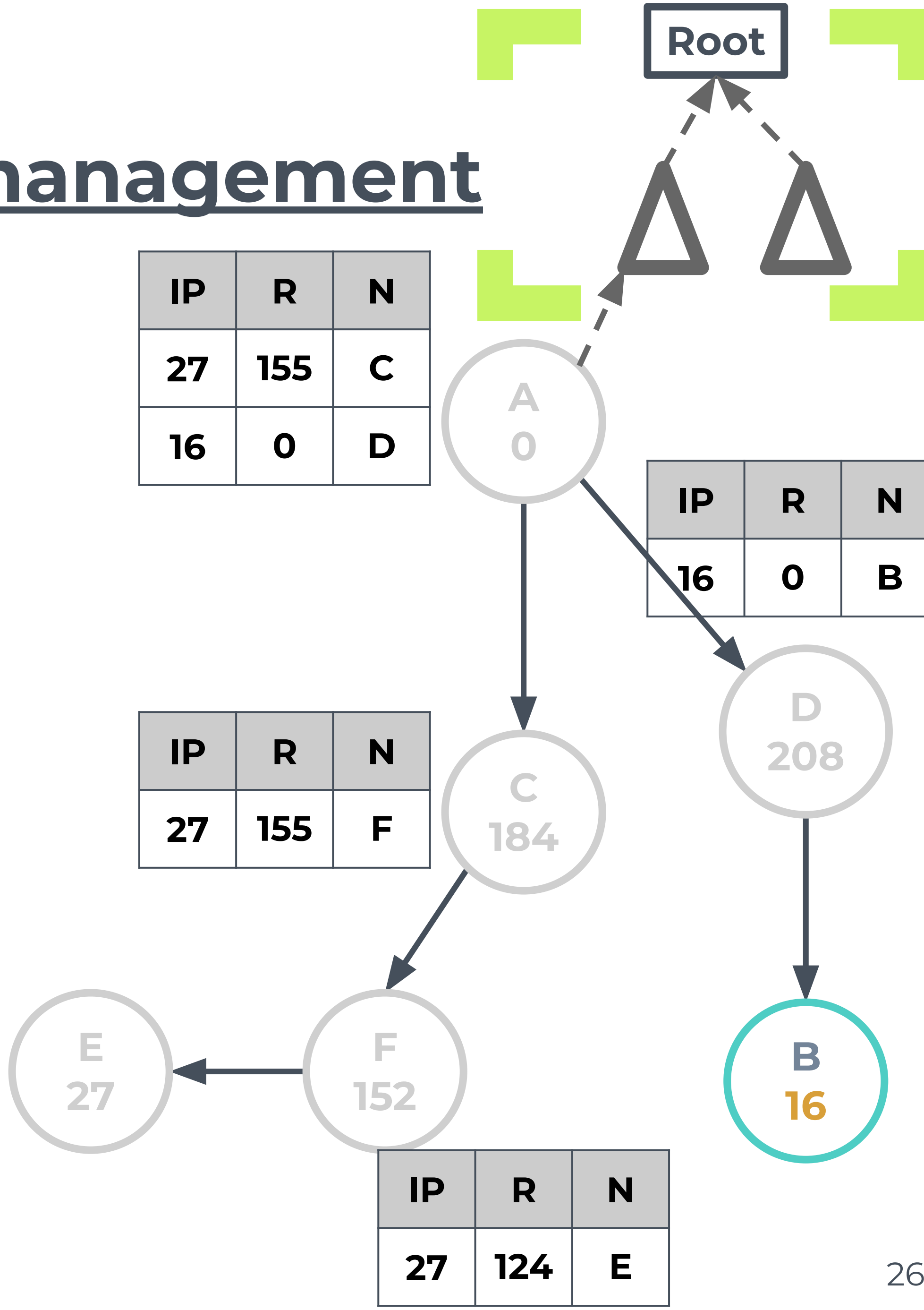
IP	R	N
16	0	B

IP	R	N
27	155	F

IP	R	N
27	124	E

µMatrix Mobility management

- Local table updates
  - Nodes
    - From B to A
      - A is the Least Common Ancestor (LCA) of B
    - From E/F to A



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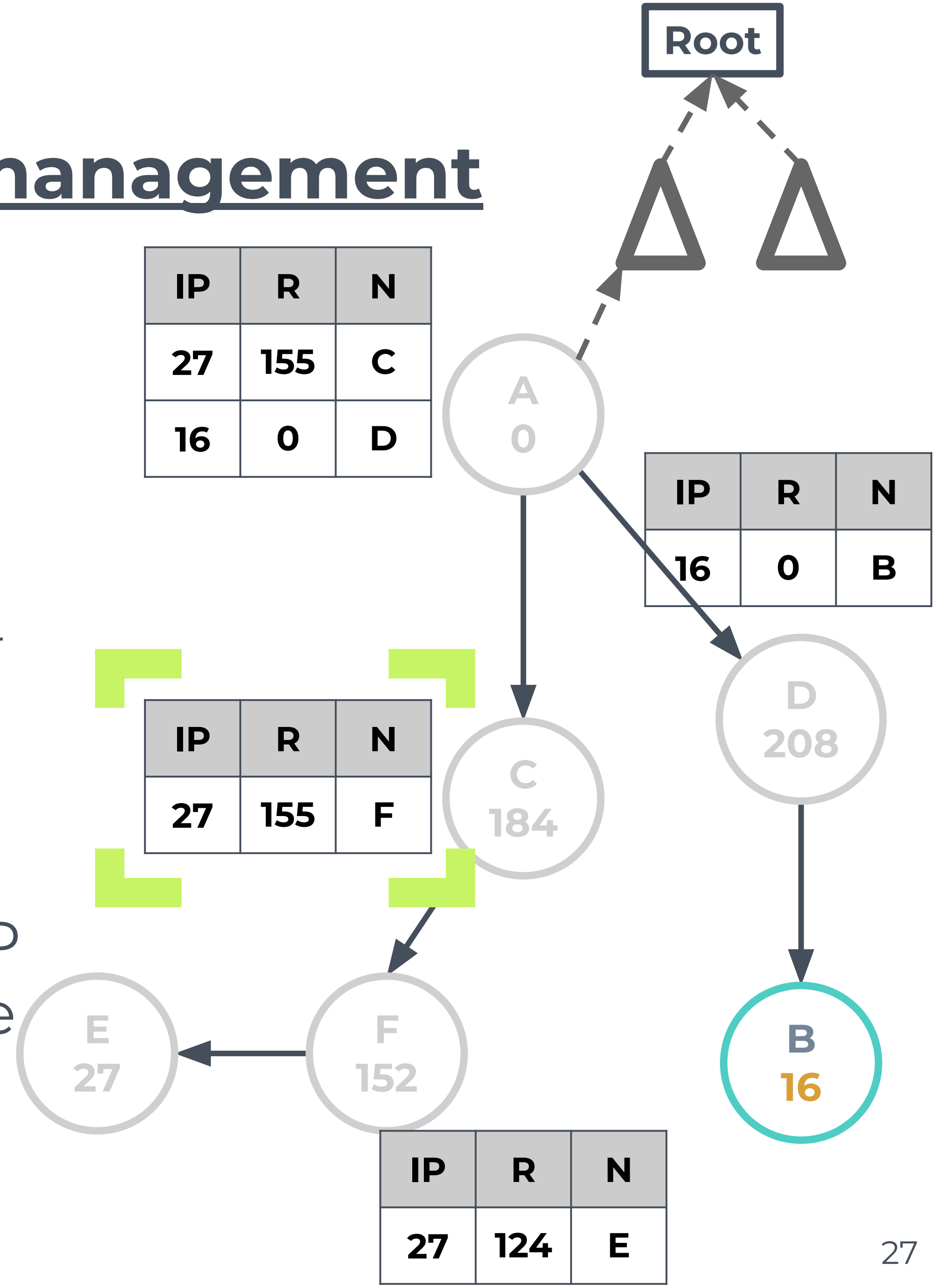
27	124	E

Design Overview

µMatrix Mobility management

- Local table updates
  - Nodes
    - From B to A
      - A is the Least Common Ancestor (LCA) of B
    - From E/F to A
- We only need **1 entry** IP for contiguous IP range (E and F)



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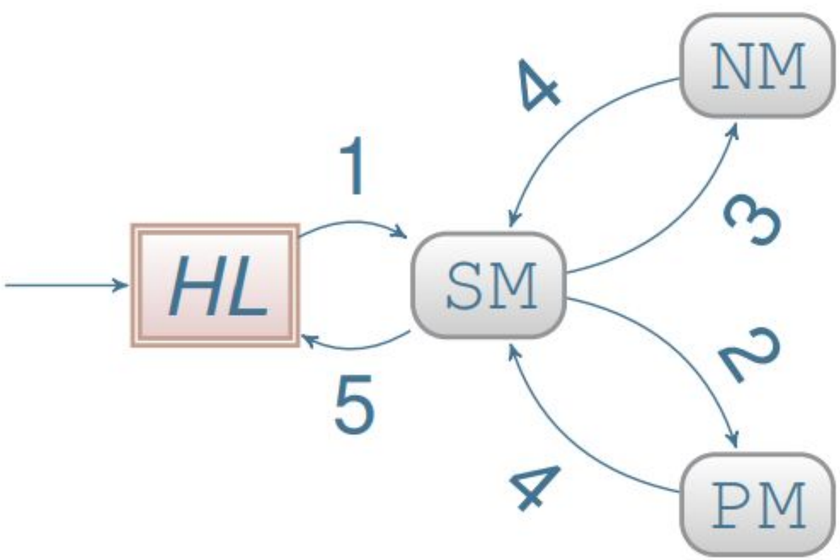
3.

Handling Mobility

1. State machine
2. Mobility detection
3. Handle node mobility

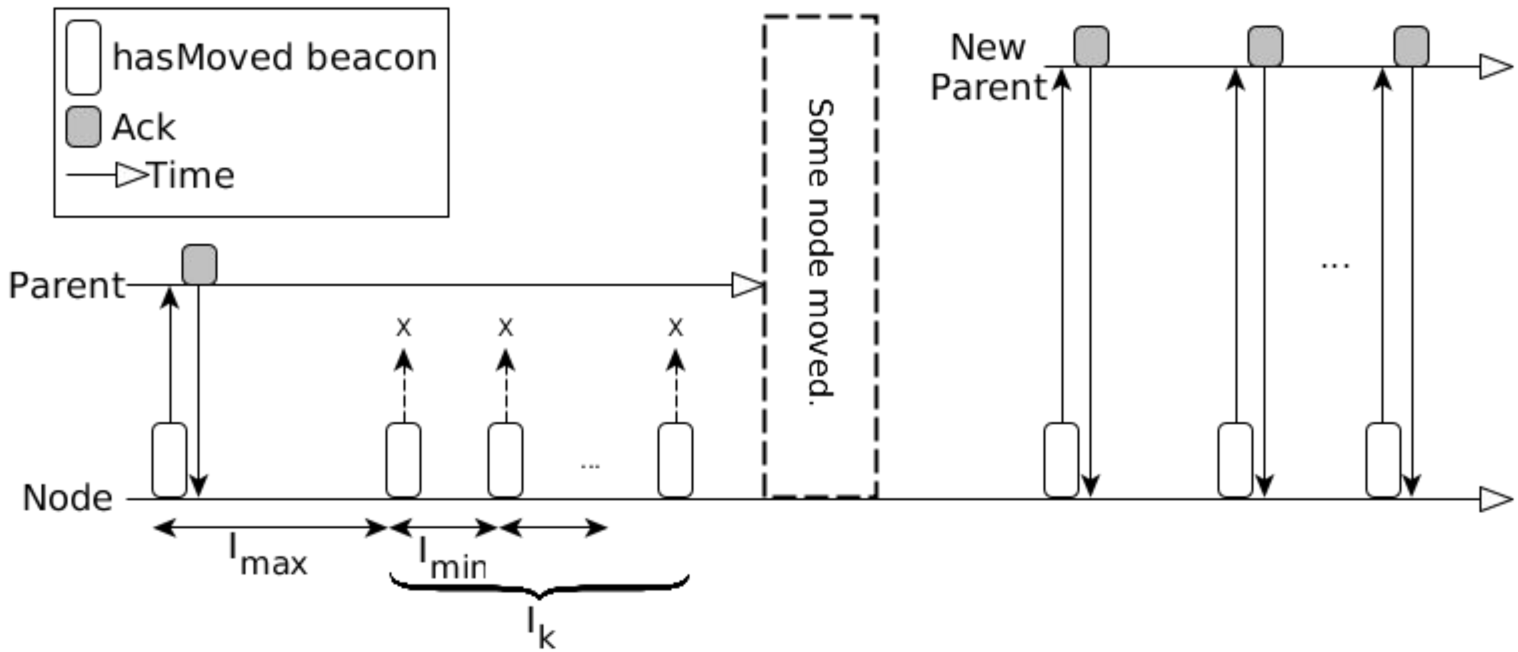
Handling Mobility

µMatrix Mobile engine - State Machine



HL	Home Location
SM	Someone Moved
NM	Node Moves
PM	Parent Moves
1	IPparent does not answer
2	Children are active
3	Children are NOT active
4	CTparent does not answer
5	IPparent is back

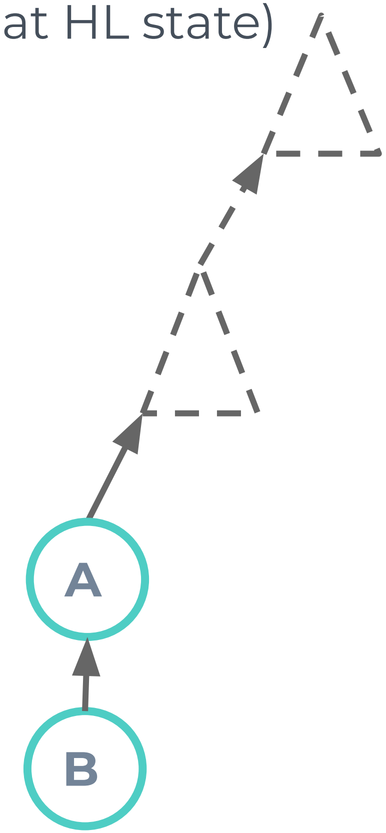
µMatrix Mobile engine - Mobility detection



µMatrix Mobile engine - Leaf node moves

Static situation

(nodes at HL state)



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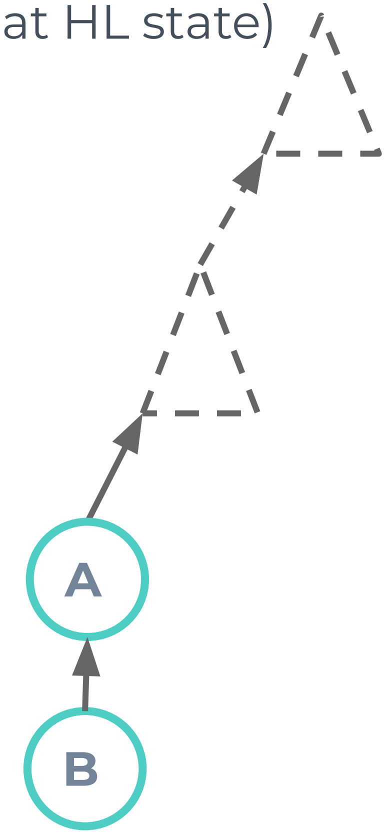
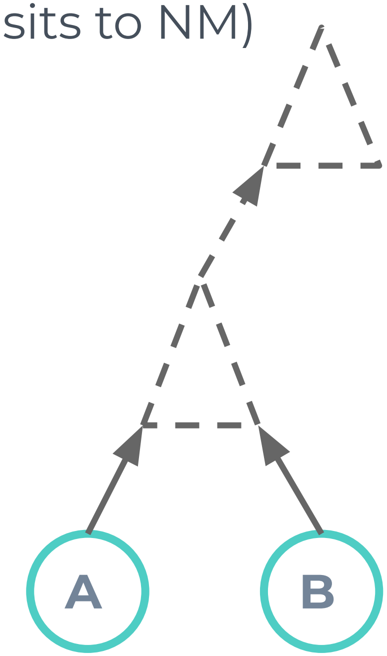


B moves

(B transits to NM)



Handling Mobility

µMatrix Mobile engine - Leaf node moves

Static situation

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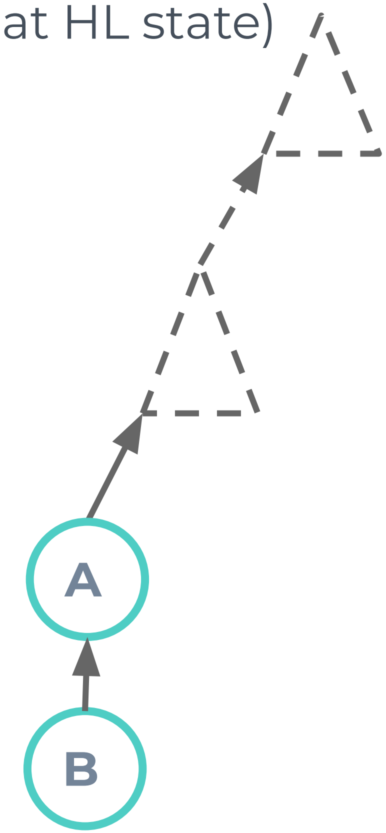

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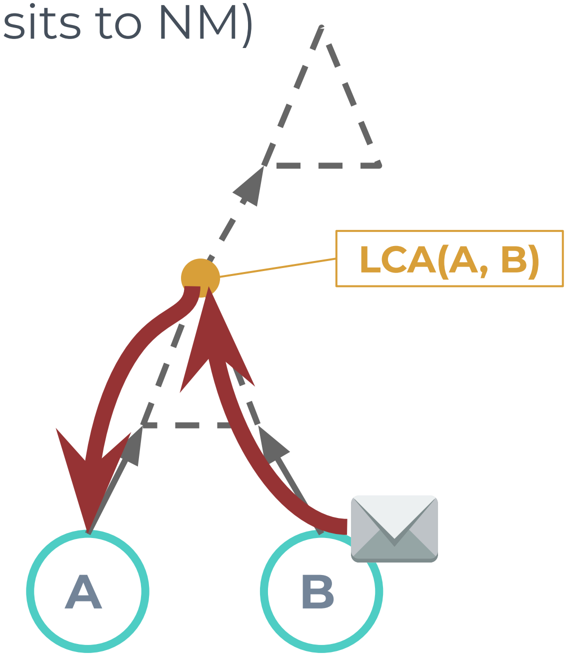
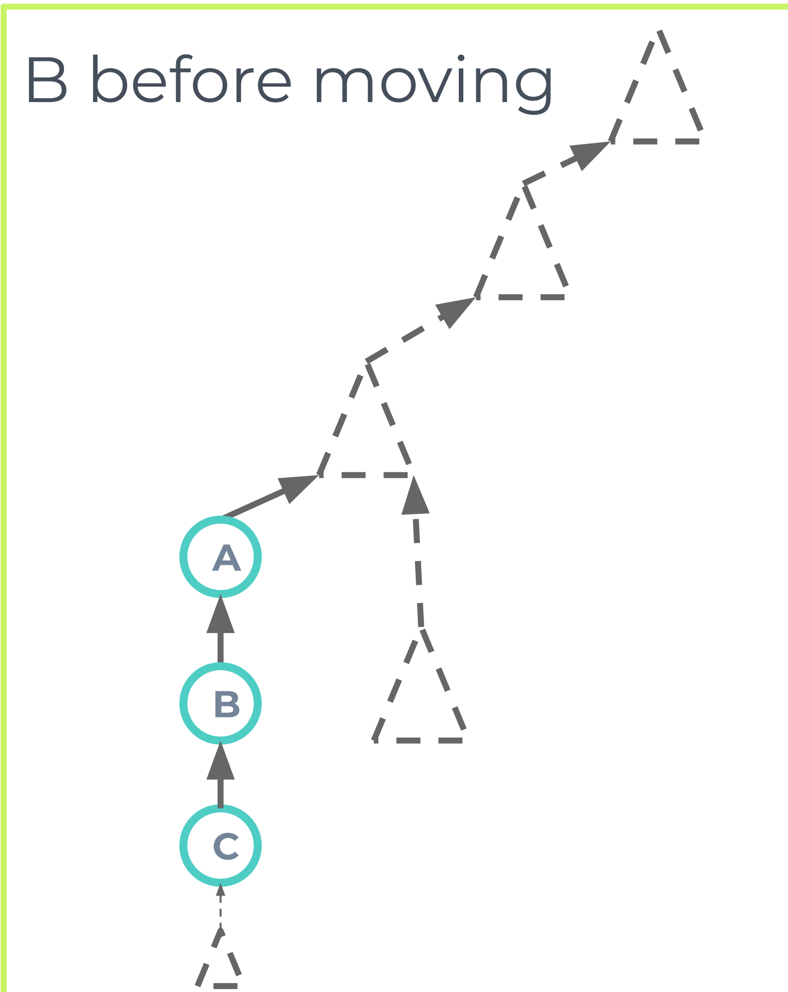
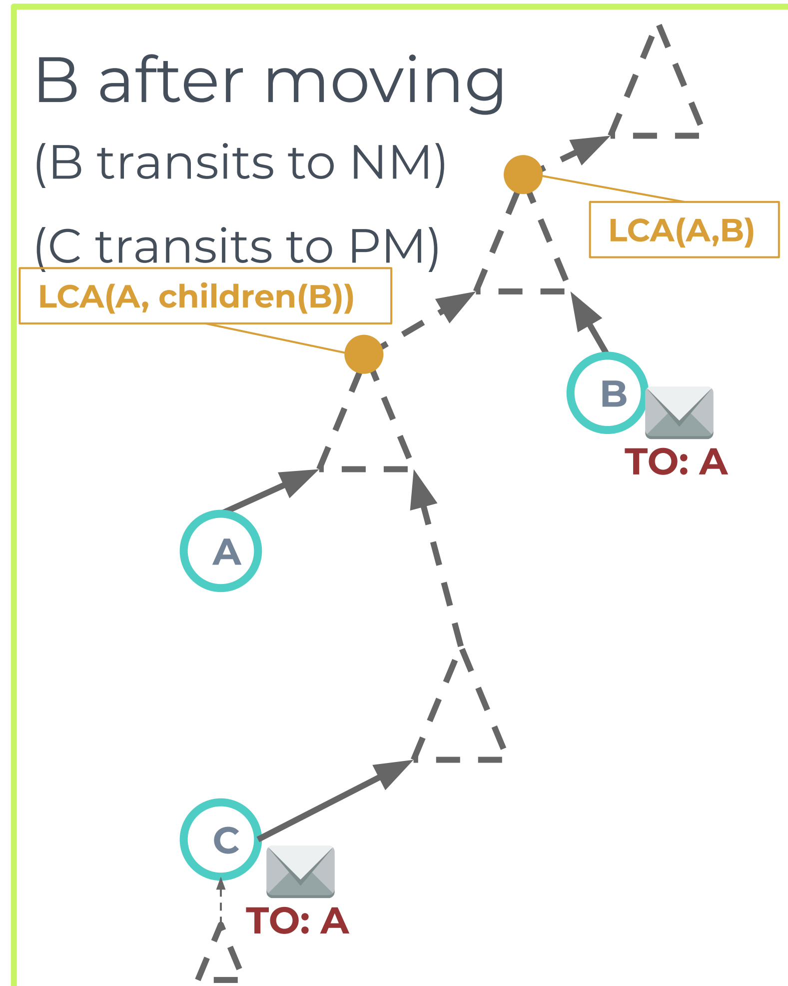


Handling Mobility

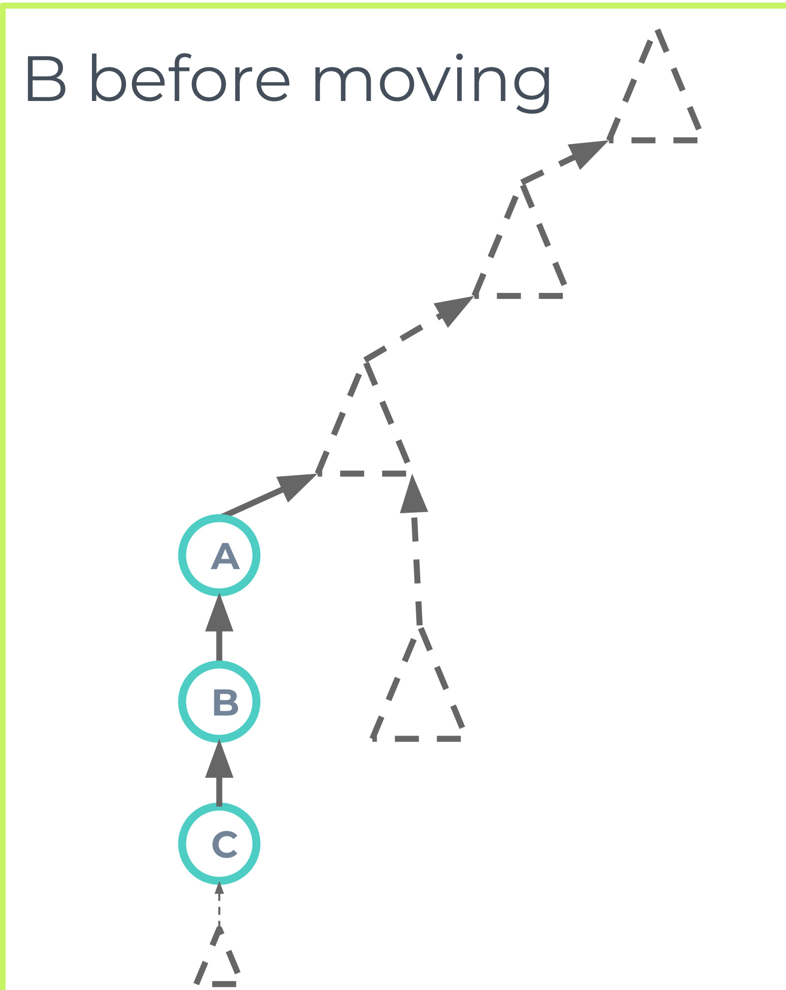
µMatrix Mobile engine - Non-Leaf node moves

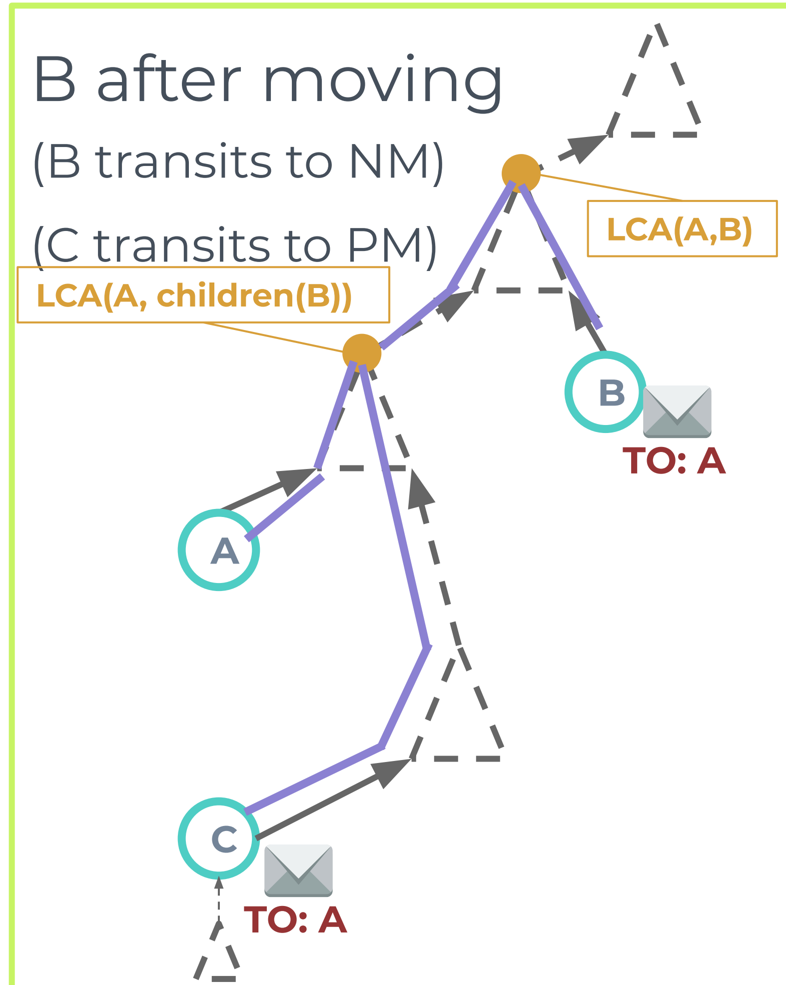




Handling Mobility

µMatrix Mobile engine - Non-Leaf node moves





4.

Complexity Analysis

1. Memory
2. Control messages

Complexity analysis

- The memory footprint to manage the mobility of one node μMatrix is

$$\mathcal{M}(u) = O(depth(Ctree))$$

Collection Tree

Complexity analysis

- The memory footprint to manage the mobility of one node μMatrix is

$$\mathcal{M}(u) = O(depth(Ctree))$$

Collection Tree

- The control message complexity of μMatrix to perform routing under mobility is

$$\mathcal{M}sg(\mu Matrix) = \mathcal{M}sg(\mu Matrix^{\mathtt{hM}}) + \mathcal{M}sg(\mu Matrix^{\mathtt{kR}})$$

Mobility detection cost

Route rebuild cost

Complexity analysis

- The memory footprint to manage the mobility of one node μMatrix is

$$\mathcal{M}(u) = O(depth(Ctree))$$

Collection Tree

- The control message complexity of μMatrix to perform routing under mobility is

$$\mathcal{M}sg(\mu Matrix(Ctree)) = O\left(\frac{m \times I_k}{I_{min}} + \frac{n}{I_{max}}\right) + O\left(\frac{m \times \Delta}{\delta} depth(Ctree)\right)$$

m, *n* - mobile and static nodes respectively,
$\mathbf{\Delta}$ - time away from home location.
I_{min}, I_{max}, I_K, δ - Reverse trickle param.

5.

Experiments

1. Mobility model
2. Parameters
3. Results

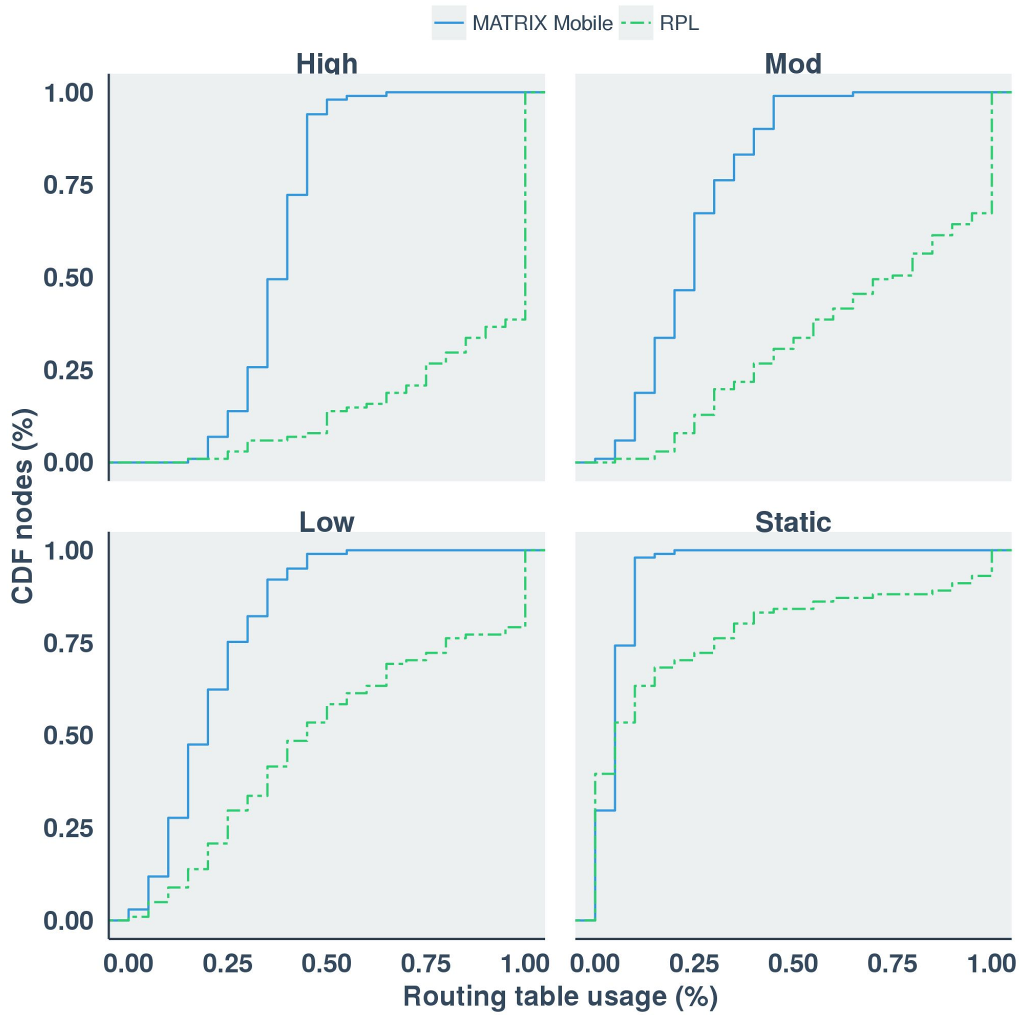
Cyclical Random Waypoint Mobility Model

1. Entities has an initial home position
2. Entities move to random destinations and speeds as in RWP
3. When an entity arrives at the destination, it stops for a given time T_{pause}
4. After n chosen destinations, the mobile entity returns to its initial position.

Simulation parameters

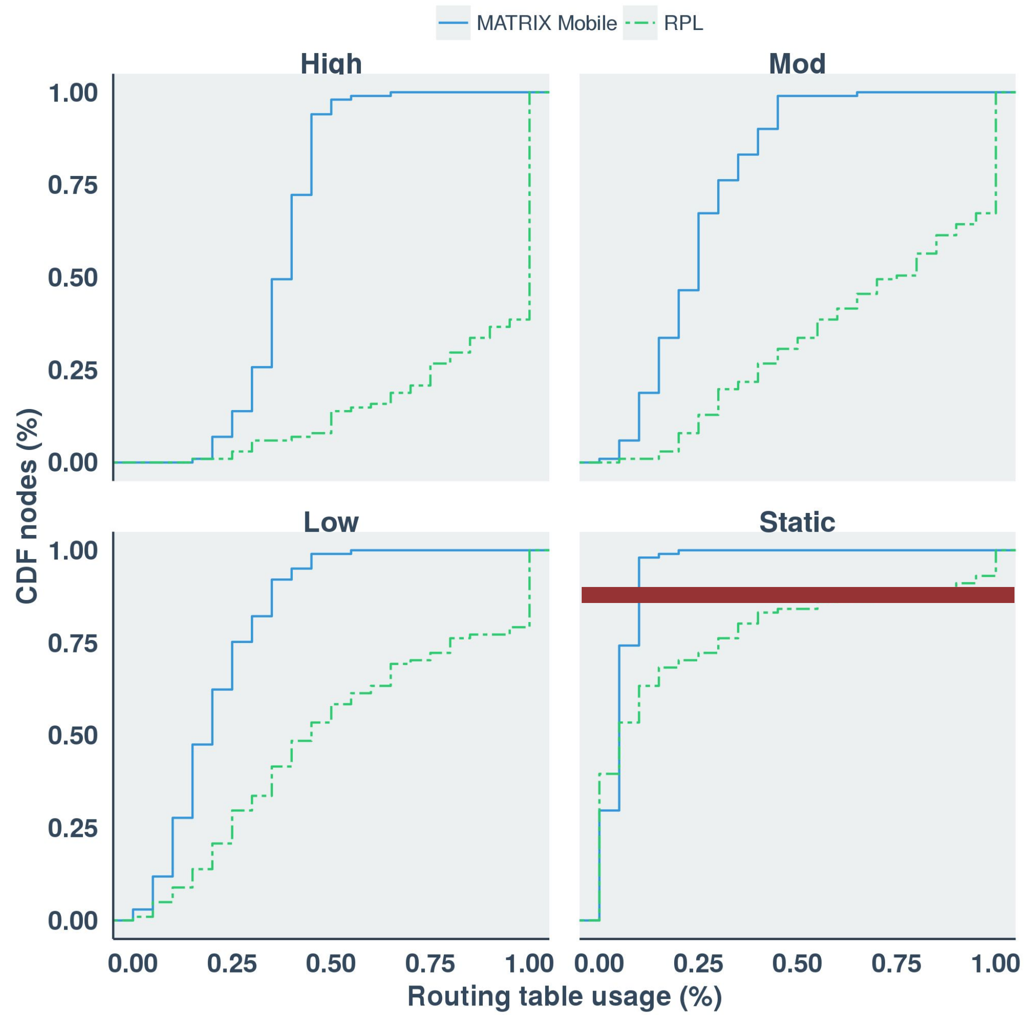
Parameter	Value		
% mobile nodes	**Low**	**Moderate**	**High**
	5%	10	15%
Node speed	Constant 4 m/s		
Tpause	Constant 300 s		
# nodes stop	Uniform Dist. in [1, 3] stops		
# nodes	101		
Application data packets	20 pks/node, 1 pkt/min		
Radio range	50m UDGM constant loss		
Deployment area	400m x 400m		
Reverse Trickle Timer	Imax= 60s,Imin= 1s, Ik= 3		
RPL Trickle	Imax= 60s		
keepRoute beacon period	δ = 60s		
Mtable (temporary table)	Size = 20 entries, TTLmax= 90s		

Results



MATRIX Mobile
RPL
High
Mod
Low
Static
CDF nodes (%)
Routing table usage (%)
1.00
0.75
0.50
0.25
0.00

Results

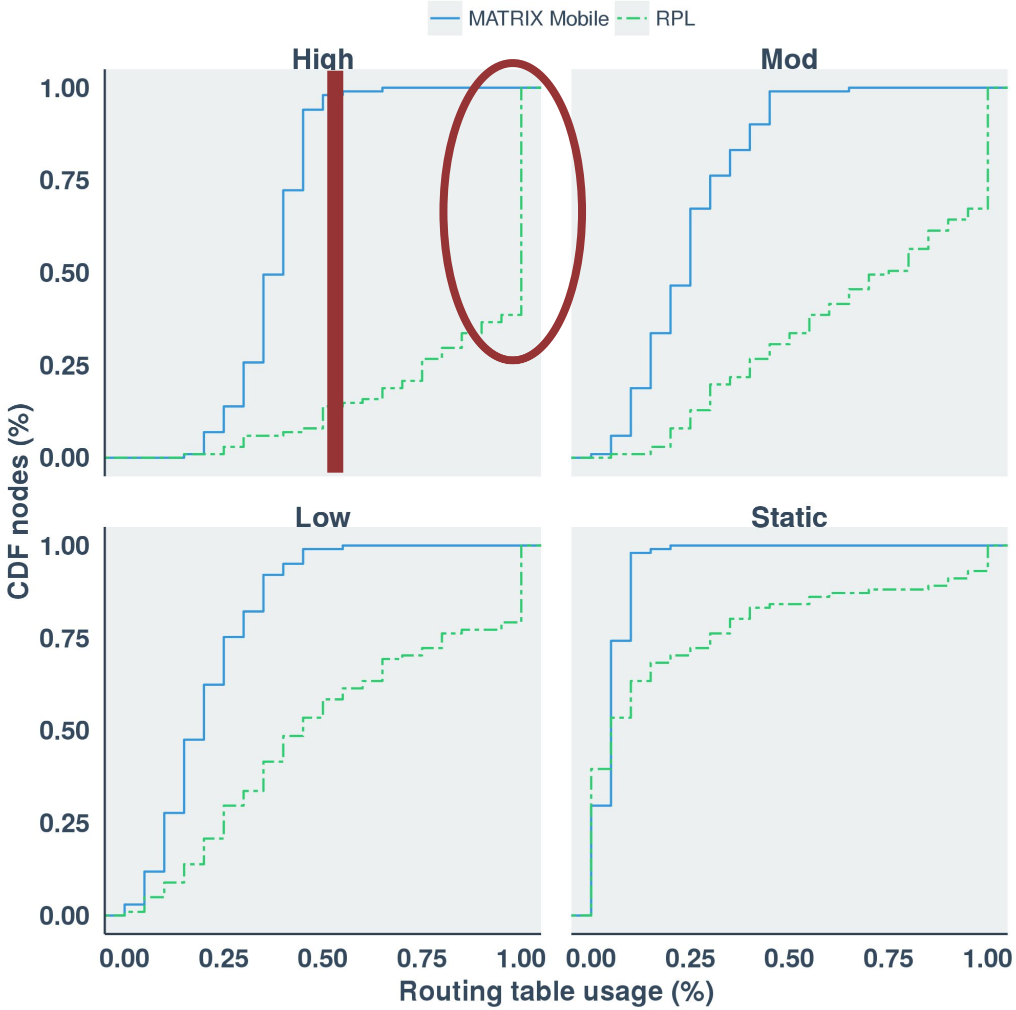


For 85% of nodes

- **RPL uses 55% of routing table,**
- **μMATRIX only 15%**

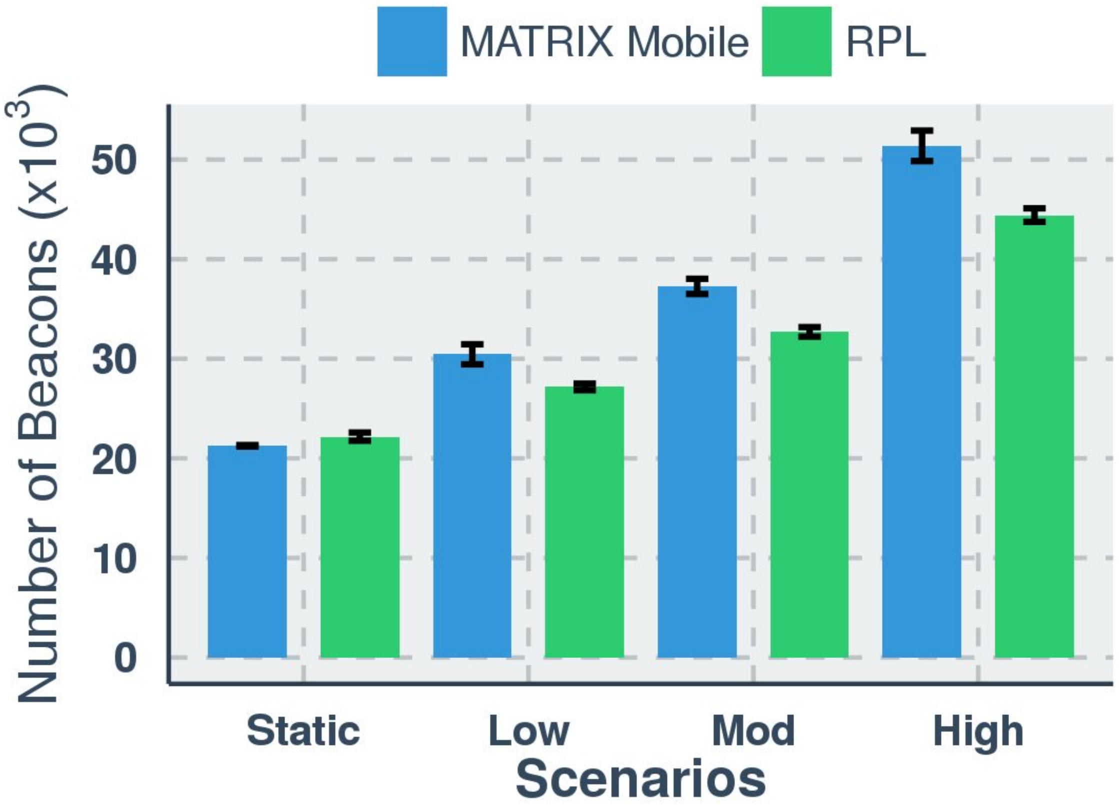
Results

- μMatrix requires 50% of available route entries
- RPL fails in routing due to full routing table



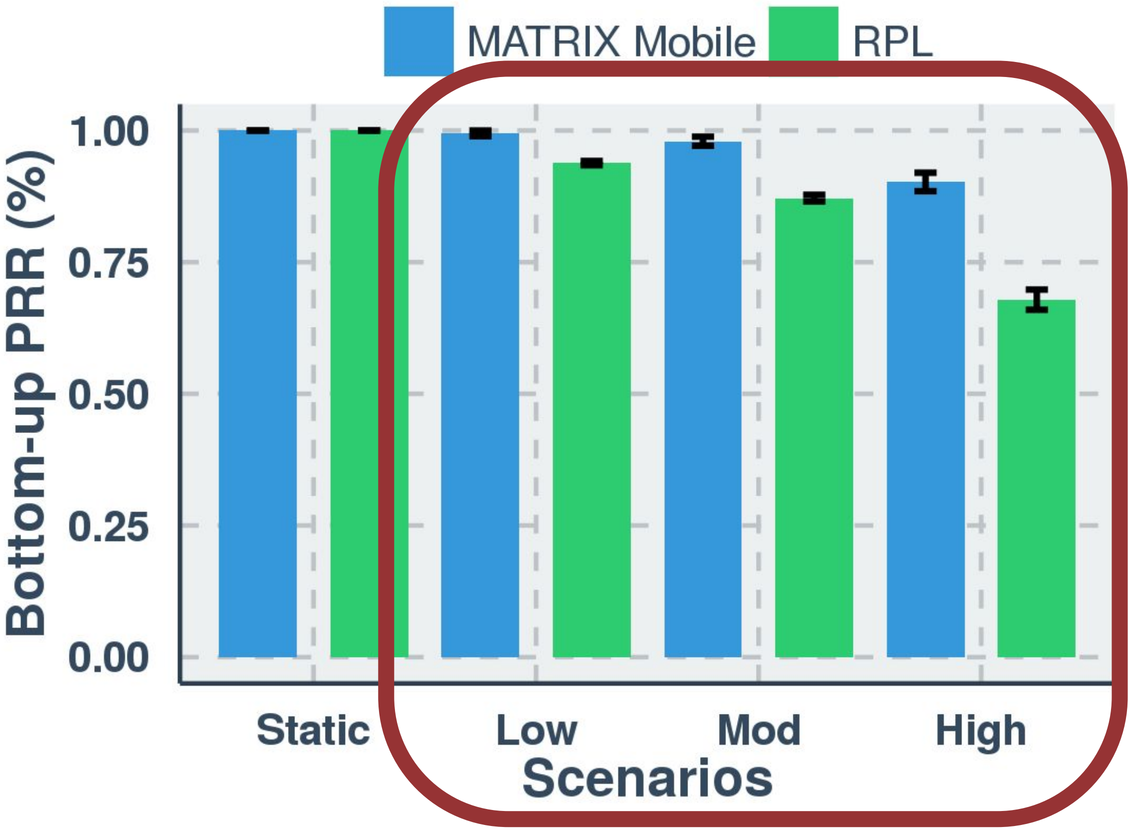
Results

- RPL sends fewer control packets than µMatrix
  - but the difference does not exceed 7.4%



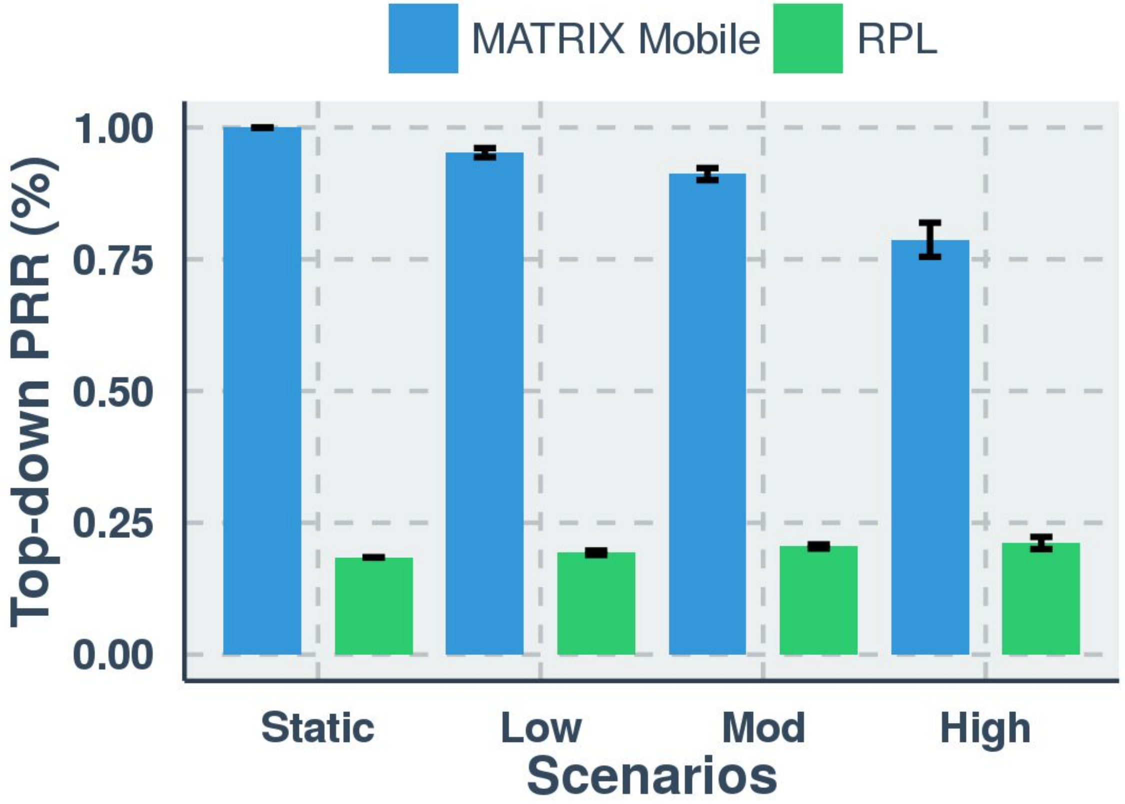
Results

- μMatrix detects mobility quickly, then it delivery more packets



Results

- μMatrix 99.9% PRR in static scenario
- μMatrix > 75% in high mobility scenario
- RPL suffers from poor reliability due a lack of memory



6.

Related work

Feature	μMatrix	RPL	Co-RPL	MMRPL	ME-RPL	mRPL	DMR	Hydro	XCTP
Bottom-up	✔	✔	✔	✔	✔	✔	✔	✔	✔
Top-down	✔	✔	✔	✔	✔	✔		✔	✔
Any-to-any	✔	✔	✔	✔	✔	✔		✔	
Address Allocation	✔								
IPv6 support	✔	✔	✔	✔	✔	✔	✔		
Memory efficiency	✔								
Fault tolerance	✔								✔
Local Repair	✔								
Topological Changes	Reverse Trickle	Trickle	Periodic fixed	Reverse Trickle-like	Trickle	Trickle	Trickle	Periodic fixed	Trickle
Constraints	Eventually nodes return to home			Need static nodes	Need static nodes	Need static nodes	Need static nodes	Need static nodes	

Related work

7.

Conclusions

Final remarks

- We presented μMatrix
  - An any-to-any routing protocol for 6LoWPAN
  - Allow mobile nodes
  - Hierarchical address allocation
  - Passive mobility detection
- We introduce CRWP
  - Suited for scenarios with cyclical movement patterns
- Future work
  - Extend experimental evaluation
    - Mobile models and traces

Thanks!

Any questions?

Bruno P. Santos, Olga Goussevskaia, **Luiz F. M. Vieira**,
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{bruno.ps, olga, **lfvieira**, mmvieira, loureiro}@dcc.ufmg.br

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I am Jayden Smith

I am here because I love to give presentations.

You can find me at @username

1.

Transition headline

Let’s start with the first set of slides

Quotations are commonly printed as a means of inspiration and to invoke philosophical thoughts from the reader.

This is a slide title

- Here you have a list of items
- And some text
- But remember not to overload your slides with content

Your audience will listen to you or read the content, but won't do both.

Big concept

Bring the attention of your audience over a key concept using icons or illustrations

You can also split your content

White

Is the color of milk and fresh snow, the color produced by the combination of all the colors of the visible spectrum.

Black

Is the color of coal, ebony, and of outer space. It is the darkest color, the result of the absence of or complete absorption of light.

In two or three columns

Yellow

Is the color of gold, butter and ripe lemons. In the spectrum of visible light, yellow is found between green and orange.

Blue

Is the colour of the clear sky and the deep sea. It is located between violet and green on the optical spectrum.

Red

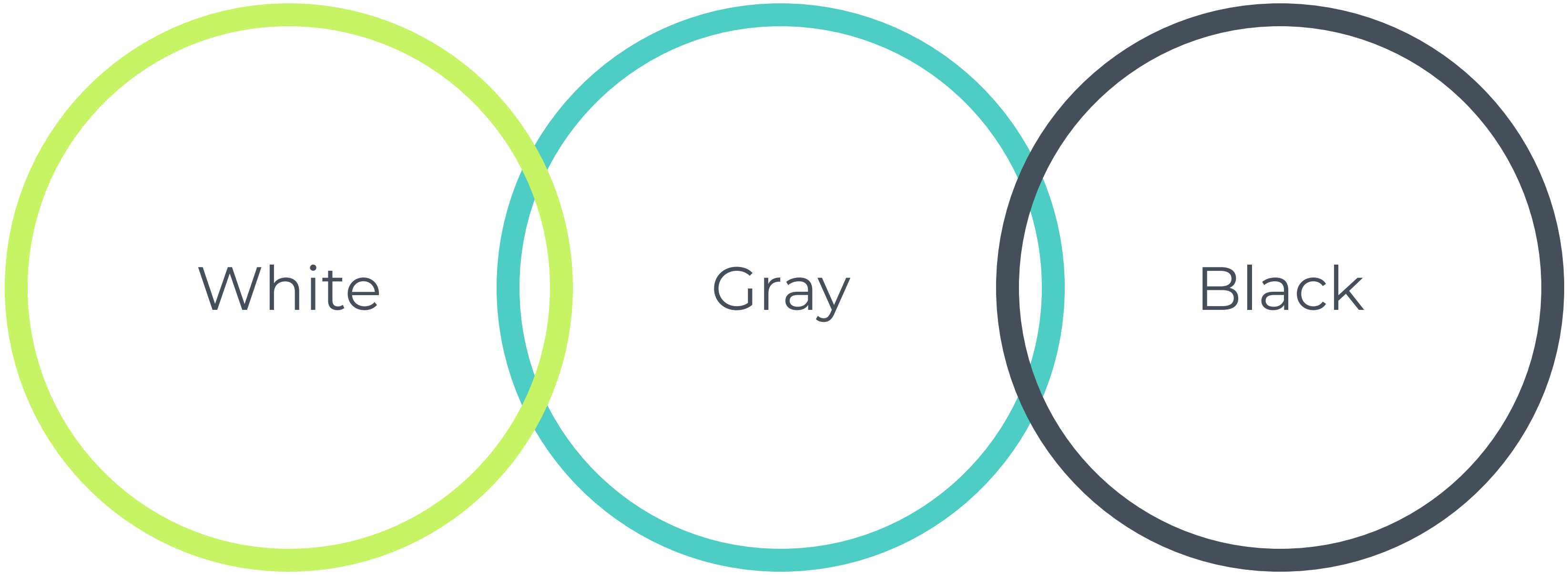
Is the color of blood, and because of this it has historically been associated with sacrifice, danger and courage.

A picture is worth a thousand words

A complex idea can be conveyed with just a single still image, namely making it possible to absorb large amounts of data quickly.


Want big impact?
Use big image.

Use charts to explain your ideas



And tables to compare data

	A	B	C
Yellow	**10**	**20**	**7**
Blue	**30**	**15**	**10**
Orange	**5**	**24**	**16**

Maps

89,526,124

Whoa! That's a big number, aren't you proud?

89,526,124$

That’s a lot of money

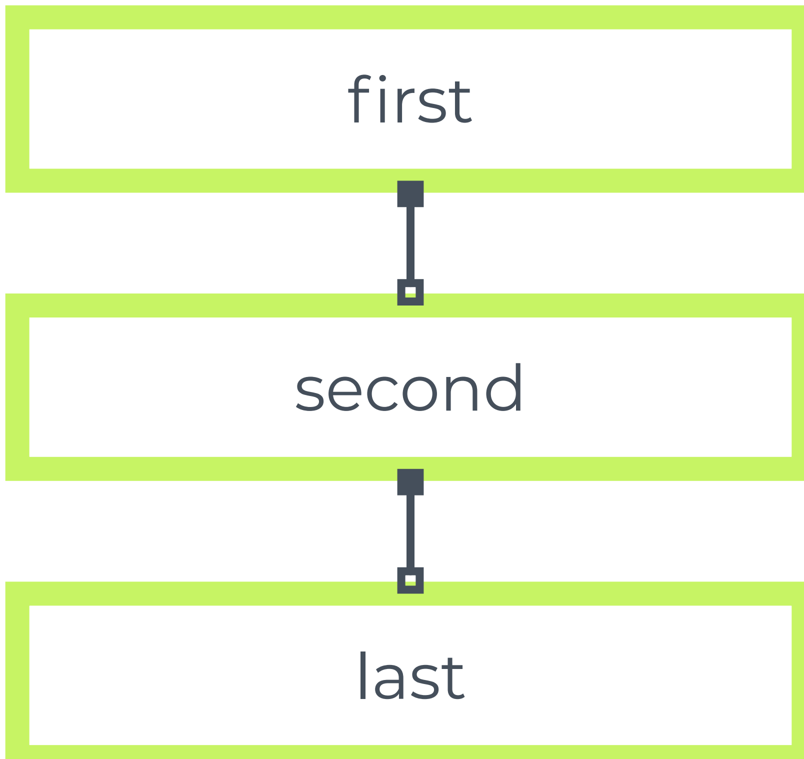
185,244 users

And a lot of users

100%

Total success!

Our process is easy



Let’s review some concepts

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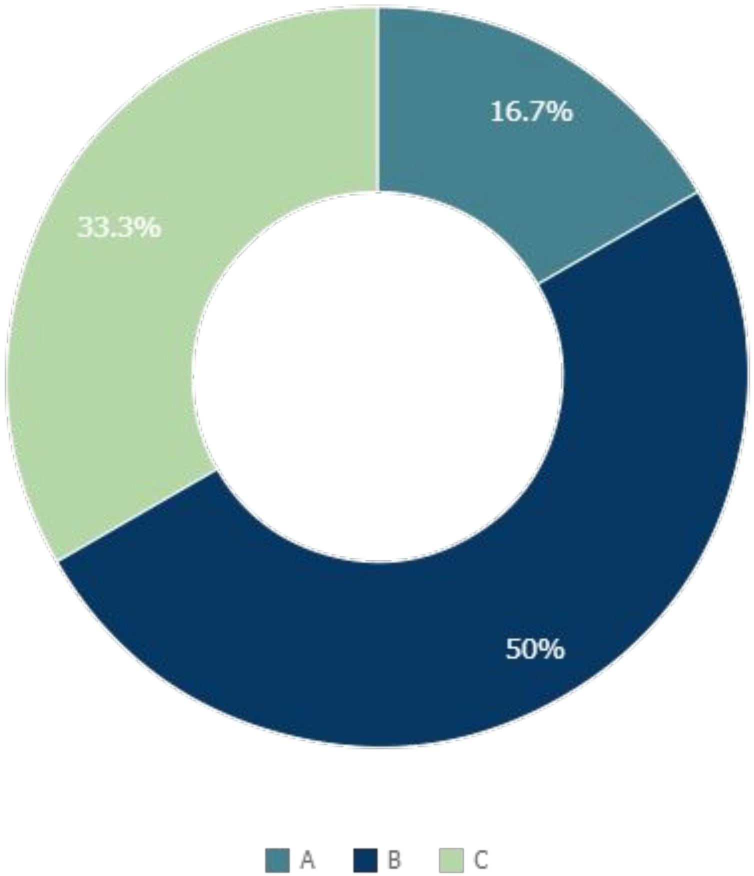

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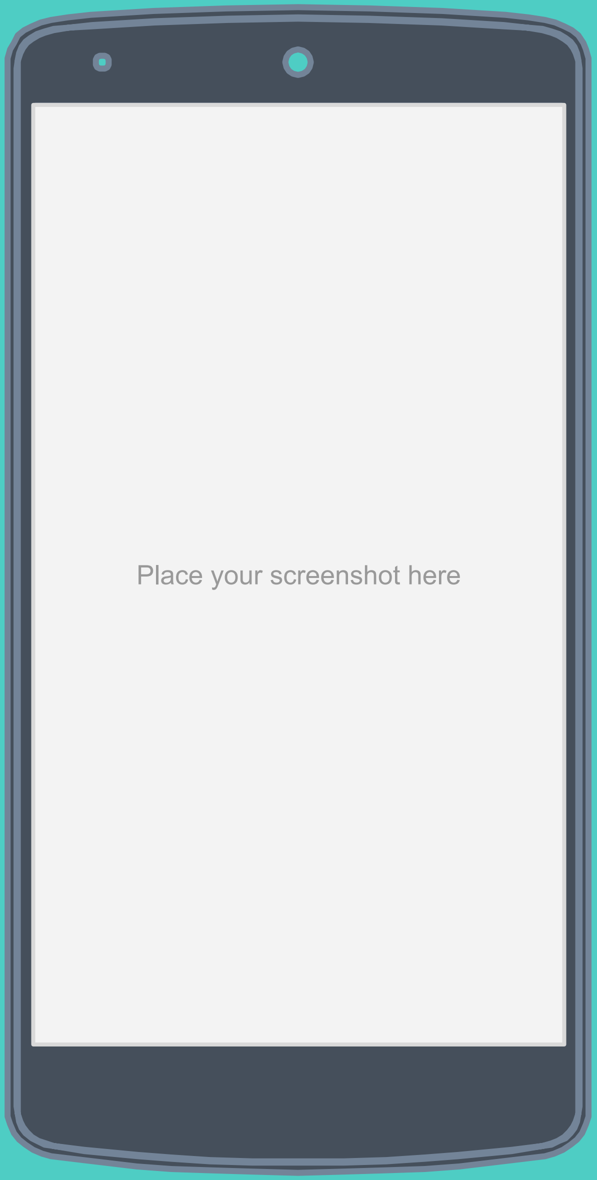

iPhone project

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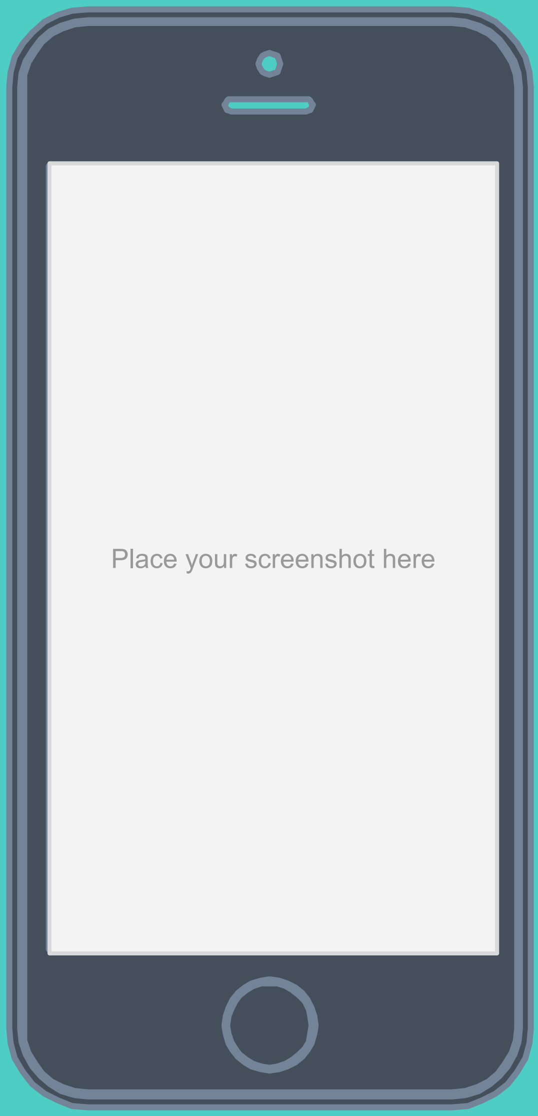

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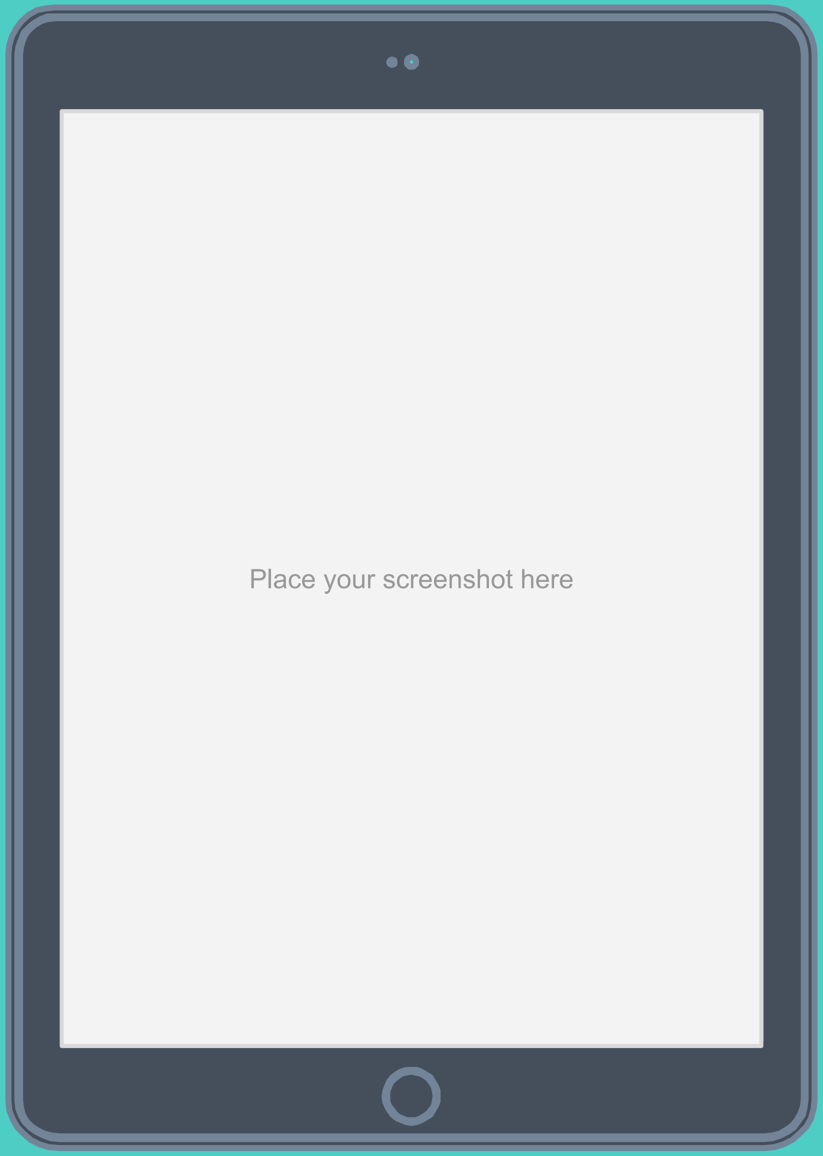

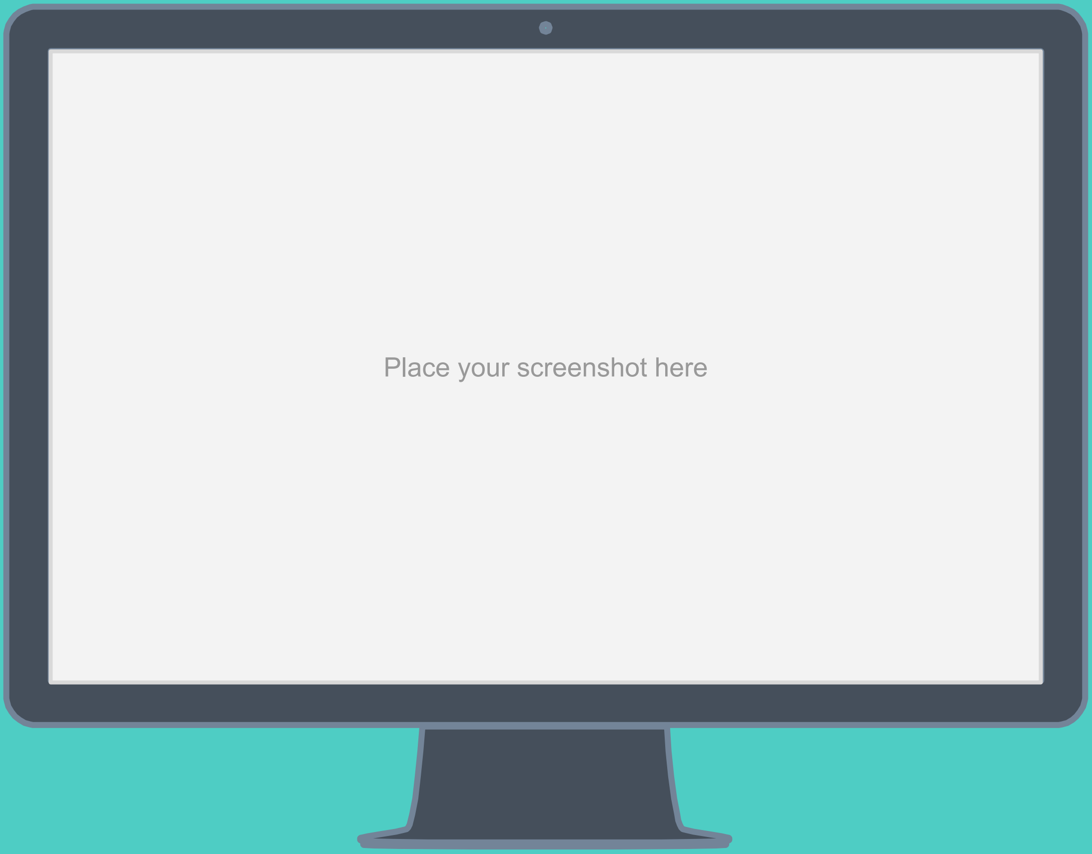

Desktop project

Show and explain your web, app or software projects using these gadget templates.

Thanks!

Any questions?

You can find me at

@username

user@mail.me

Credits

Special thanks to all the people who made and released these awesome resources for free:

- Presentation template by SlidesCarnival
- Photographs by Unsplash

Presentation design

This presentations uses the following typographies and colors:

- Titles & Body copy: **Montserrat**

You can download the fonts on this page:

https://www.google.com/fonts#UsePlace:use/Collection:Montserrat:400,700

Click on the “arrow button” that appears on the top right

- Grey **#454f5b**
- Light grey **#738498**
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- Aqua **#4ecdc4**

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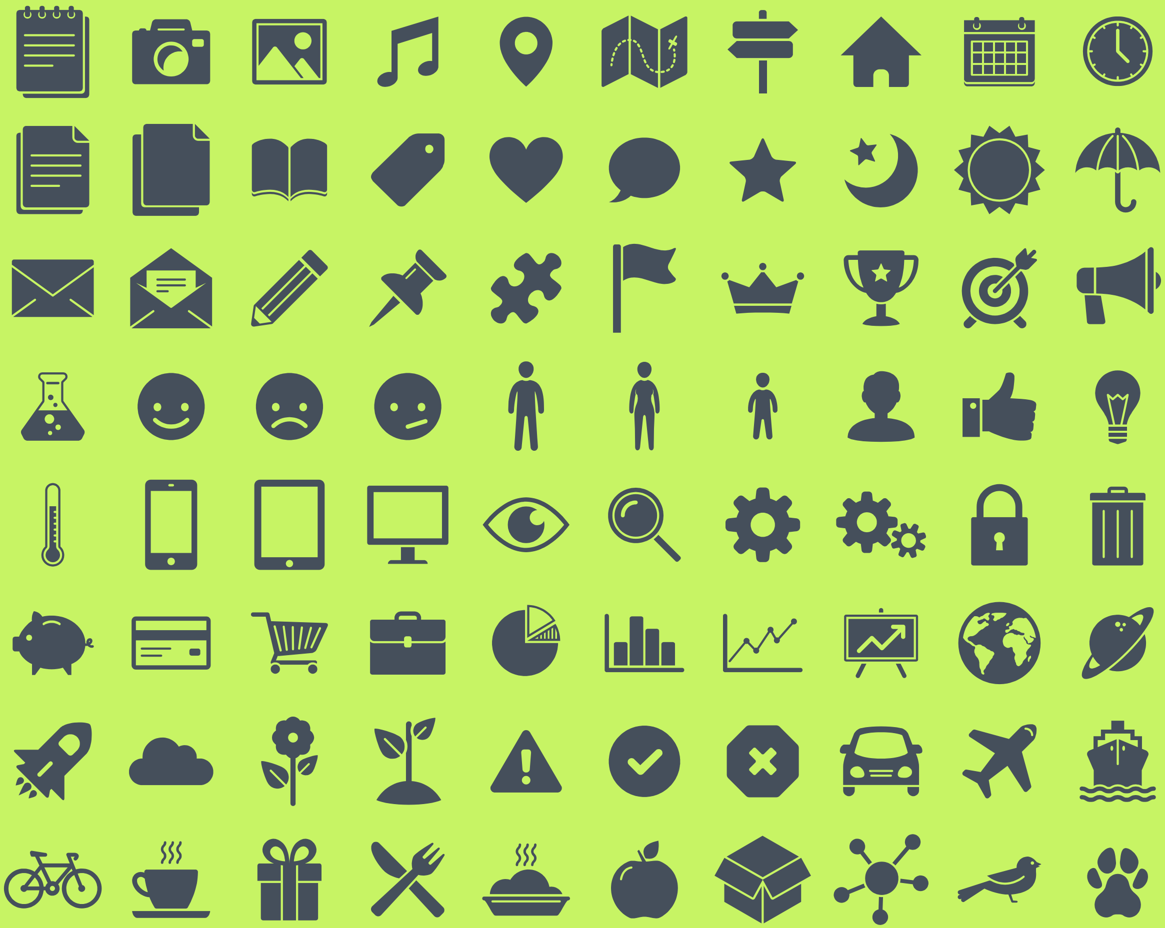

SlidesCarnival icons are editable shapes.

This means that you can:

- Resize them without losing quality.
- Change fill color and opacity.
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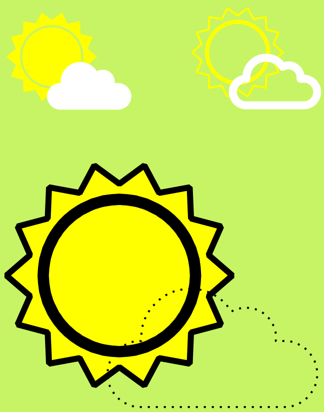
Examples:



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How? Follow Google instructions
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