User-driven Path Control through Intent-Based Networking

Anne-Ruth Meijer, Leonardo Boldrini, Ralph Koning, Paola Grosso

Responsible Internet

The **Responsible Internet** [1] is a novel security-by-design concept and extension to the internet that enables higher levels of trust and data autonomy.

It turns the Internet infrastructure from a **black box** to a ‘**glass box**’

It brings **Transparency**, **Controllability** and **Accountability** to the Internet

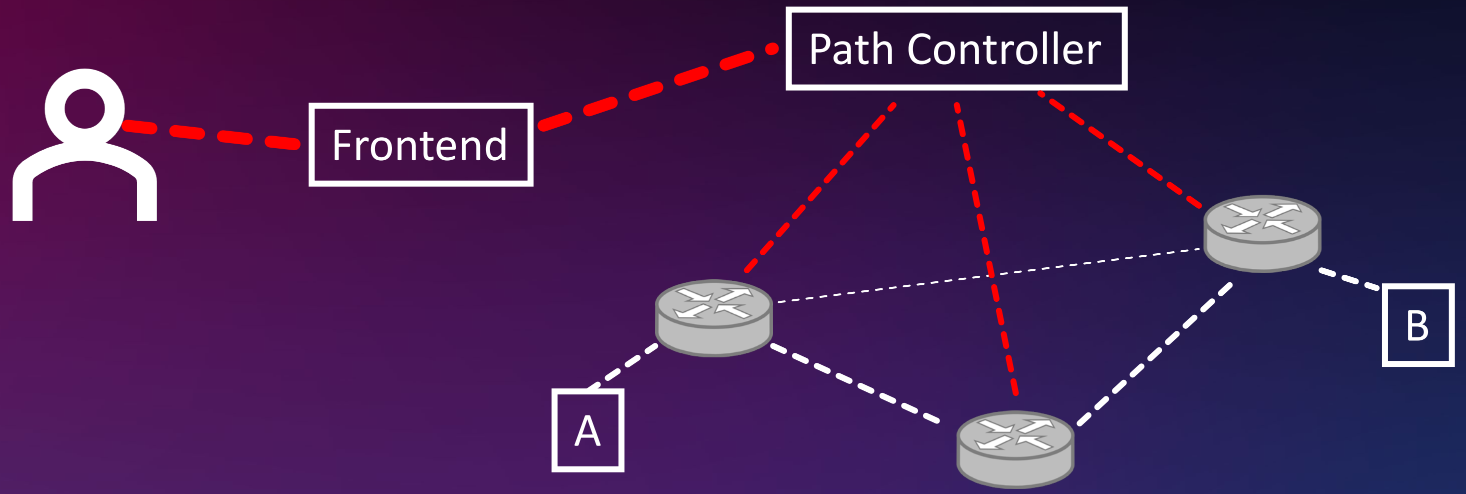
[1] Cristian Hesselman, Paola Grosso, Ralph Holz, Fernando Kuipers, Janet Hui Xue, Mattijs Jonker, Joeri de Ruiter, Anna Sperotto, Roland van Rijswijk-Deij, Giovane Moura, et al. **A responsible internet to increase trust in the digital world**. 2020.

The UPIN project

UPIN: User-driven Path verification and control for Inter-domain Networks enables users to control and verify paths that their data travels through [2]

The UPIN Framework:

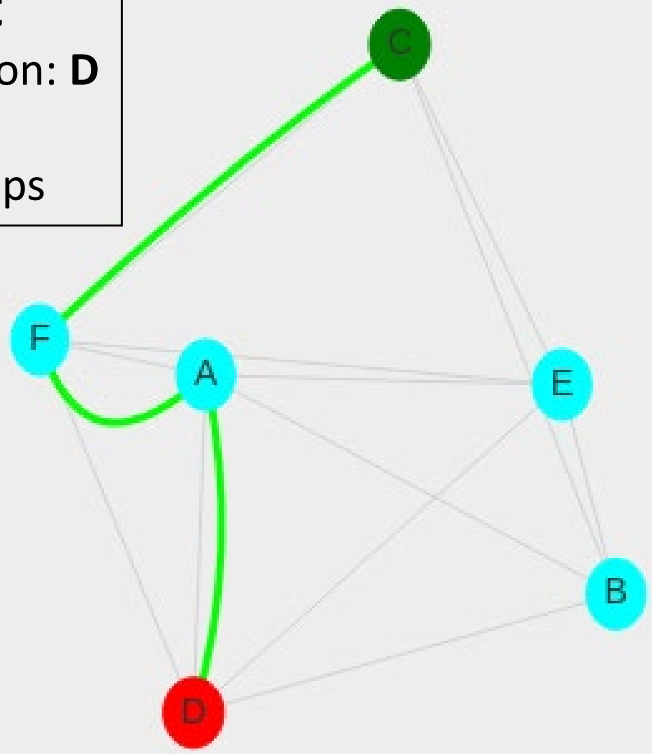
- **Frontend**
- **Path Controller**
- Domain Explorer
- Path Tracer
- Path Verifier



[2] Rodrigo Bazo, Leonardo Boldrini, Cristian Hesselman, and Paola Grosso. **Increasing the Transparency, Accountability and Controllability of multi-domain networks with the UPIN framework**. 2021

Frontend design

User Intent:
Source: **C**
Destination: **D**
Via: **A**
Max **4** hops



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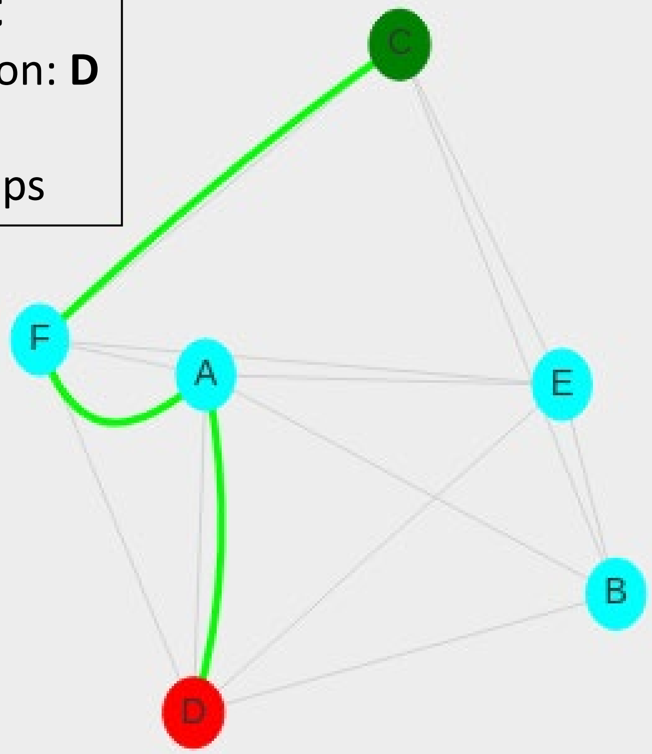

Technical centric approach:

```
define intent create_path:
    from endpoint('C')
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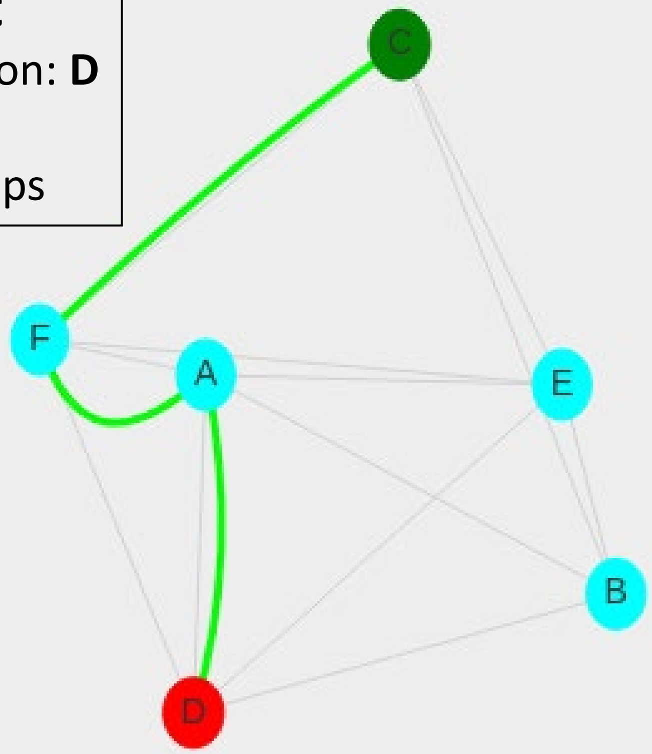

Human centric approach:

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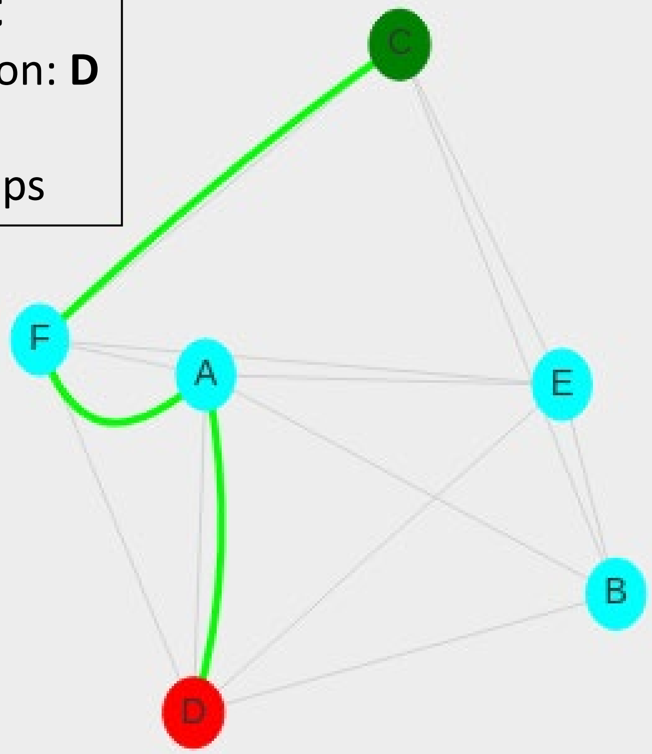

Human centric approach:

go from C to A to D with max 4 hops

frits

You want to create a path from C to D via A with a limit of 4 hops

Bot

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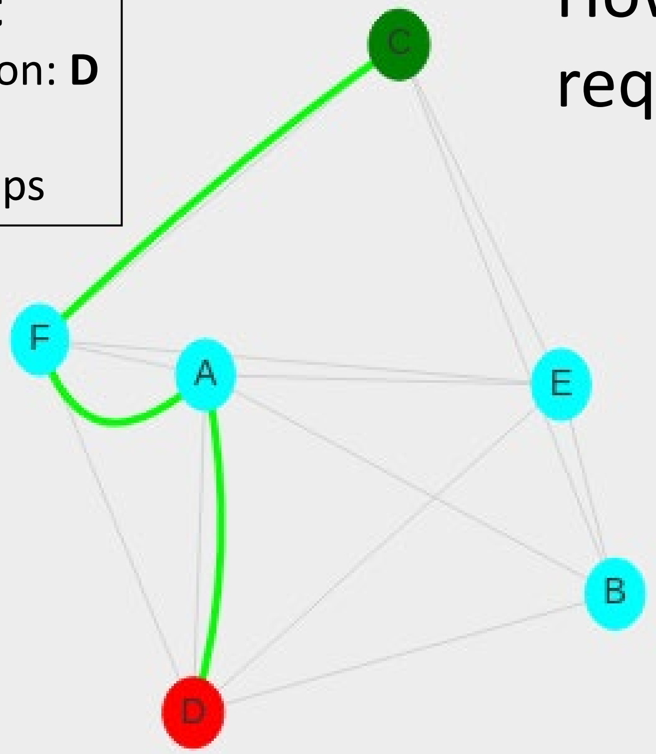
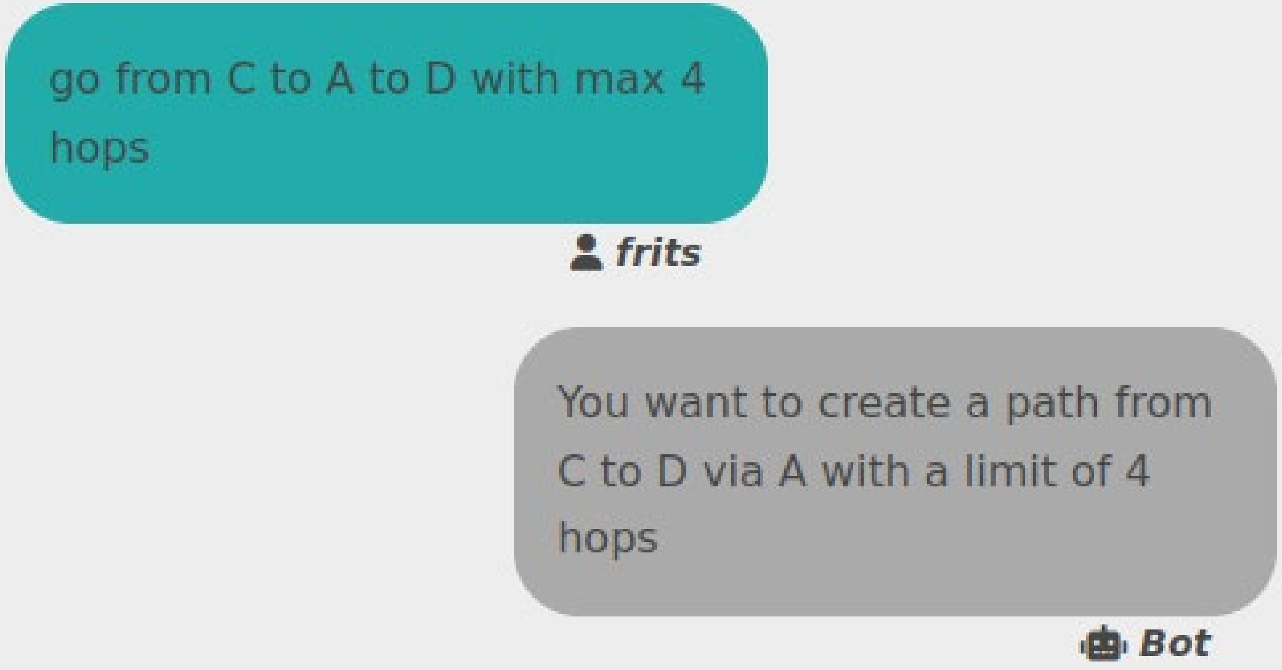
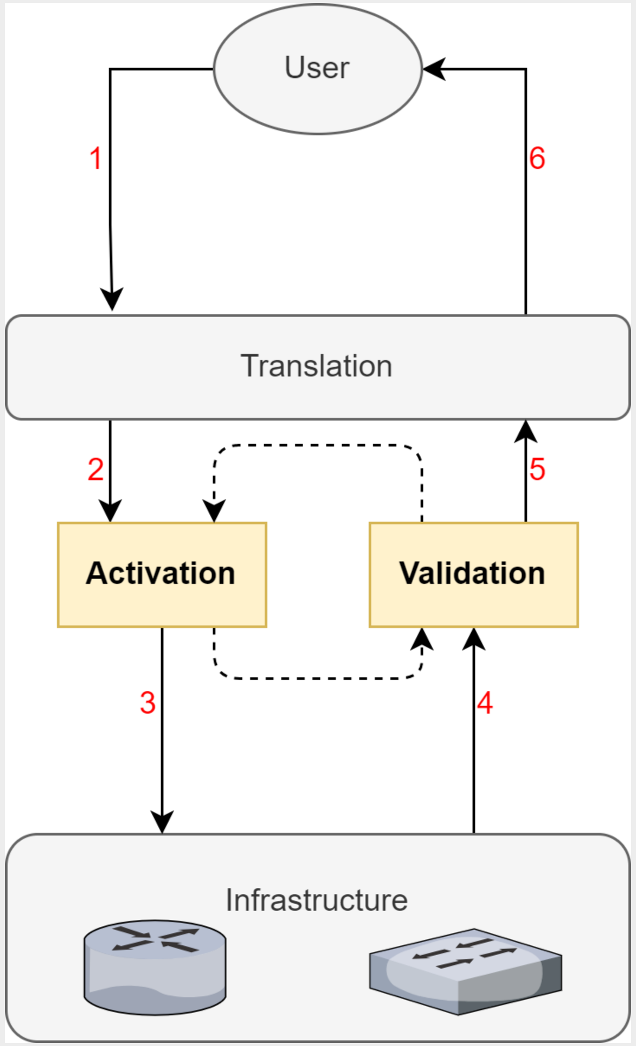


How do we design a chatbot to understand user's request on path control?



Intent Based Networking



Intent-Based Networking (IBN)[3] provides users with the ability to express a desire and translate said desire into network level configurations.

1. State intent
2. Request configuration
3. Execute configuration
4. Network-driven feedback
5. Metrics
6. Intent-based feedback

[3] A. Clemm, L. Ciavaglia, L. Z. Granville, and J. Tantsura, "Intent-Based Networking - Concepts and Definitions," Internet Engineering Task Force, Internet-Draft. 2022. Available: https://datatracker.ietf.org/doc/html/draft-irtf-nmrg-ibn-concepts-definitions-09

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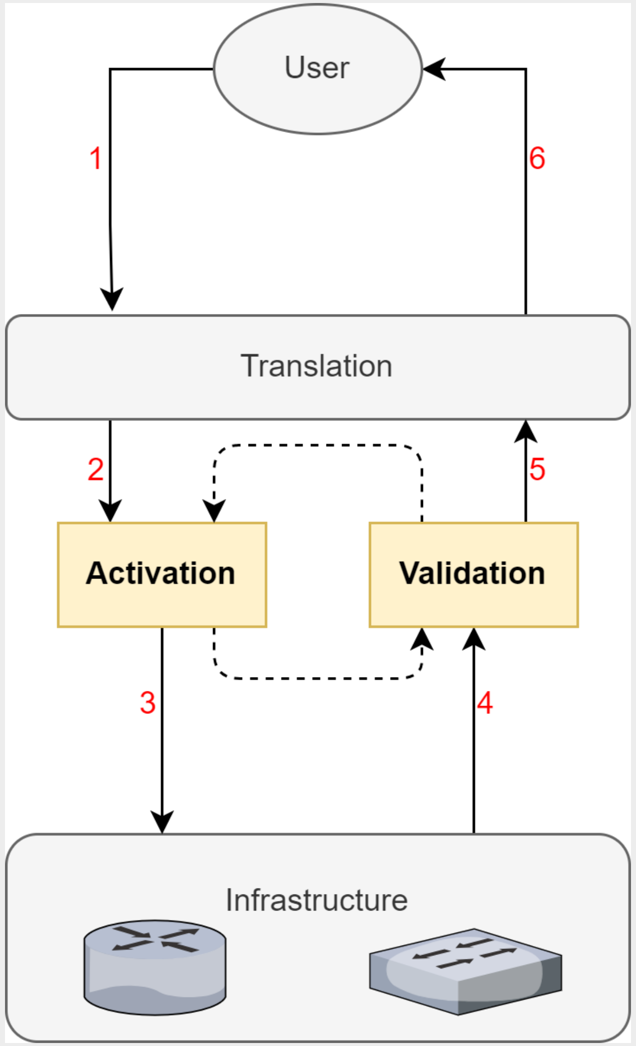

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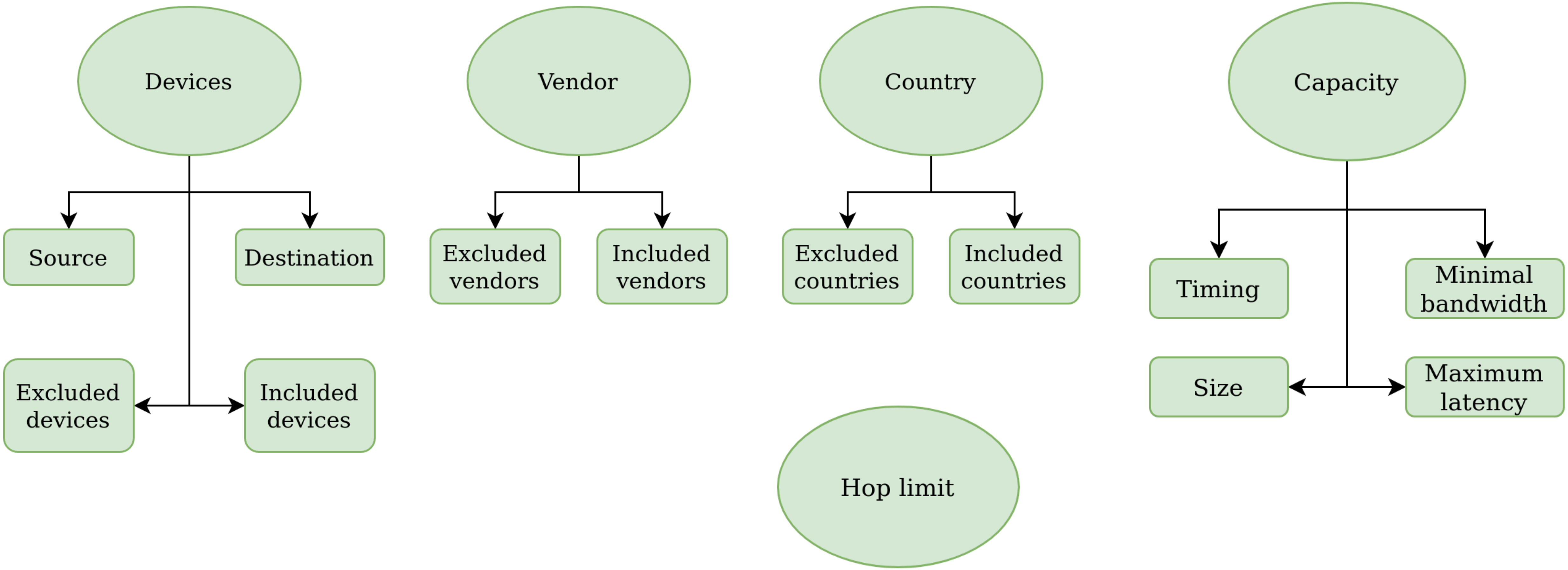
Path properties: Entities



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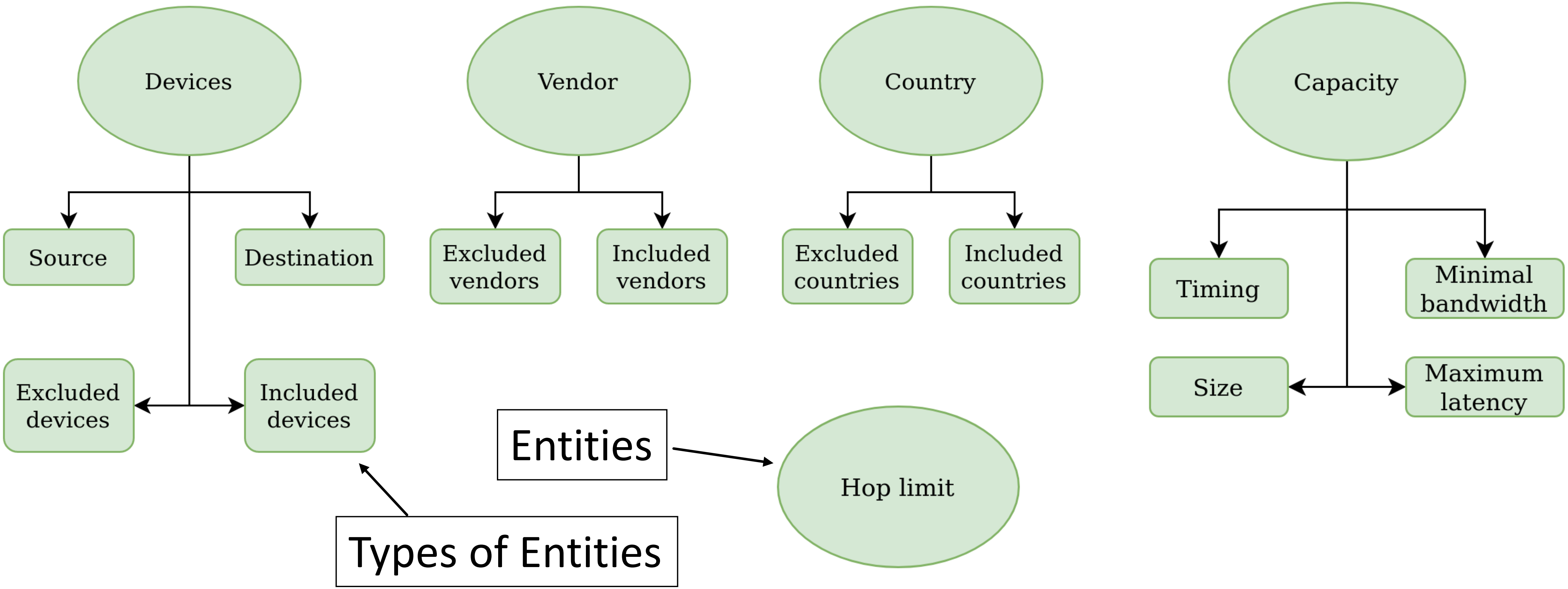

Design Considerations

		Control	Required Knowledge	Language	Network
define intent create_path: **from** endpoint('C') **to** endpoint('D') **allow** device('A') **with** hops('max','4')	**Technical centric approach**	Unlimited	Network and Syntax	Restricted	UPIN demo
go from C to A to D with max 4 hops *frits* You want to create a path from C to D via A with a limit of 4 hops *Bot*	**Human centric approach**	Unlimited	Network	Unrestricted	UPIN demo

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Our model needs to both extract entities, understand their type, and ultimately understand the intent of the user.

Natural Language Understanding Pipelines

We implement a Chatbot with Rasa Open Source[4].

Rasa provides a dialogue system based on machine learning to understand **natural language**.
We expand the Baseline pipeline with additional featurizers to improve the performance of our model.

Name	Configuration
P1 (Baseline)	WhitespaceTokenizer, RegexFeaturizer, DIETclassifier, EntitySynonymMapper, ResponseSelector, FallbackClassifier
P2	P1 + CountVectorsFeaturizer
P3	P1 + LexicalSyntacticFeaturizer
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Pipeline improvements: featurizers

The two featurizers we added to aid our model are **CountVectors** and **LexicalSyntactic**.

CountVectors disregards word order and focuses on the amount of similar words in a sentence.

LexicalSyntactic creates additional features for entity extraction since our intent can contain several different entities. This method creates features based on the lexical and syntactic properties of the tokens.

CountVectorsFeaturizer

["From","A", "to", "B", "to", "C"]

"From"	"A"	"to"	"B"	"C"
1	1	2	1	1

LexicalSyntacticFeaturizer

["excluding", "Cisco", "devices"]

	"excluding"	"Cisco"	"devices"
Title	0	1	0
suffix3	"ing"	"sco"	"ces"
prefix2	"ex"	"Ci"	"de"

Performance metrics

$$TP = true\ positives$$
$$FP = false\ positives$$
$$TN = true\ negatives$$
$$FN = false\ negatives$$

$$accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

$$precision = \frac{TP}{TP + FP}$$

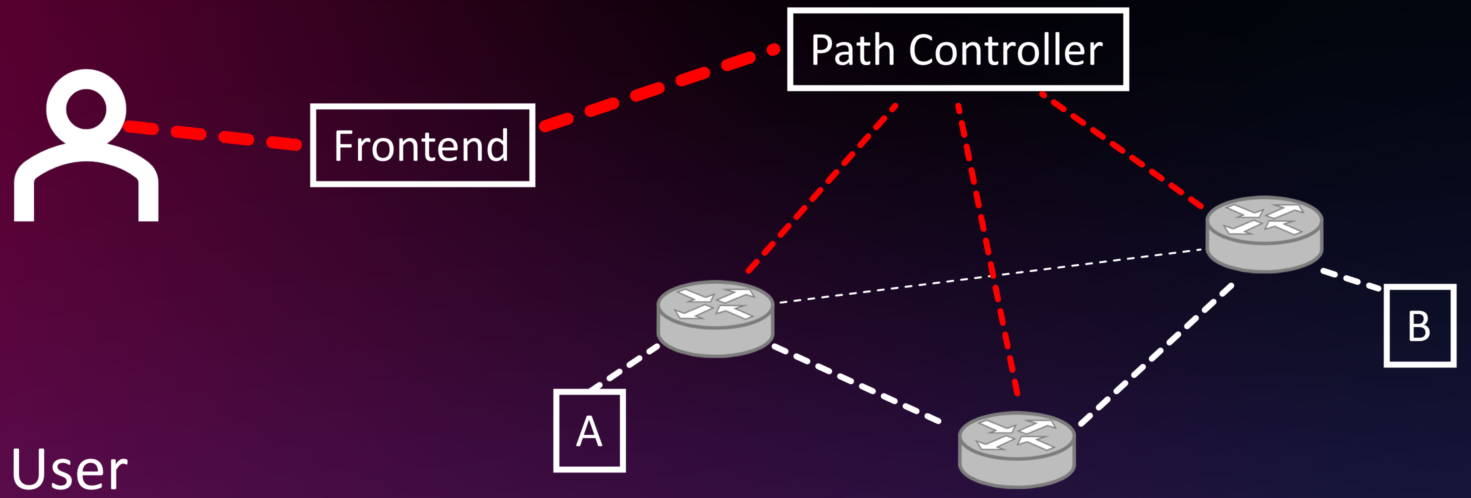
$$recall = \frac{TP}{TP + FN}$$

$$F1 = \frac{2 \bullet (precision \bullet recall)}{precision + recall}$$

Performance Results

	P1	P2	P3	P4
Accuracy intent	0.63	0.84	0.83	0.85
Precision intent	0.63	0.86	0.83	0.86
Recall intent	0.63	0.84	0.83	0.85
F1 score intent	0.63	0.83	0.83	0.85
Accuracy entity	0.74	0.82	0.93	0.93
Precision entity	0.33	0.46	0.85	0.83
Recall entity	0.29	0.46	0.80	0.80
F1 score entity	0.31	0.46	0.82	0.82

Takeaway



- Increase **transparency** to the User

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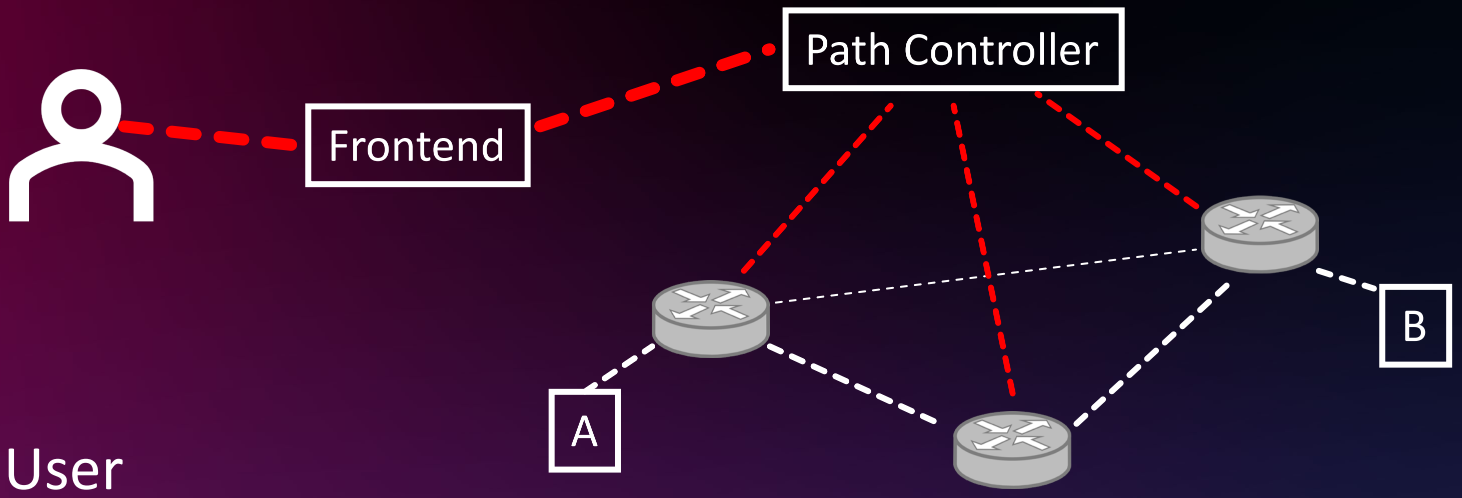

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- **Frontend** Design that includes a Chatbot

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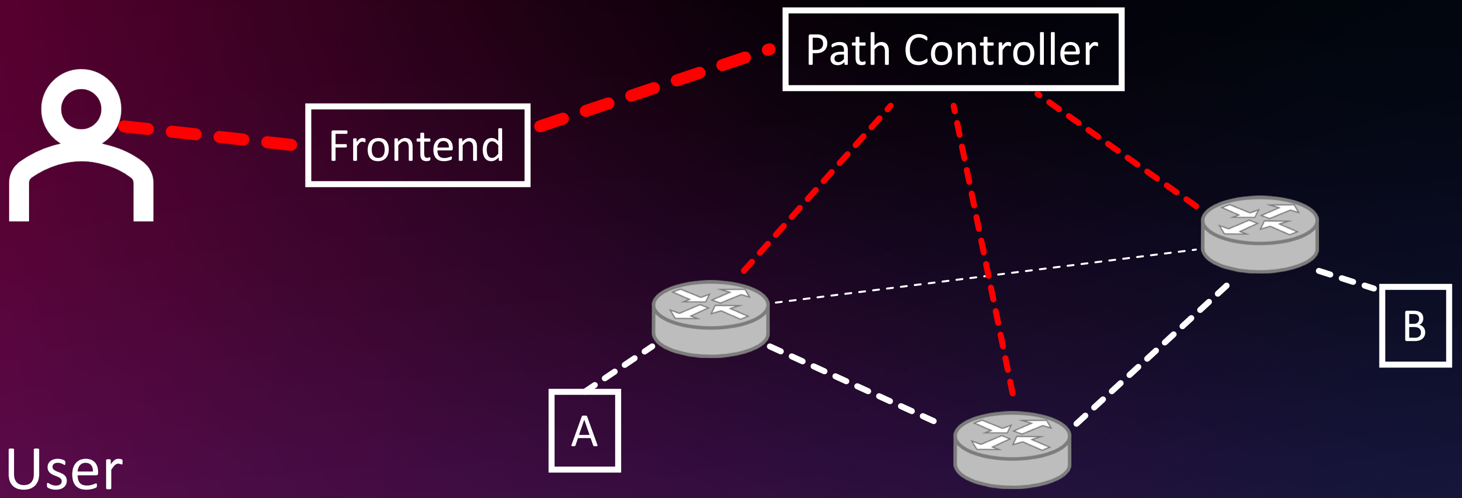

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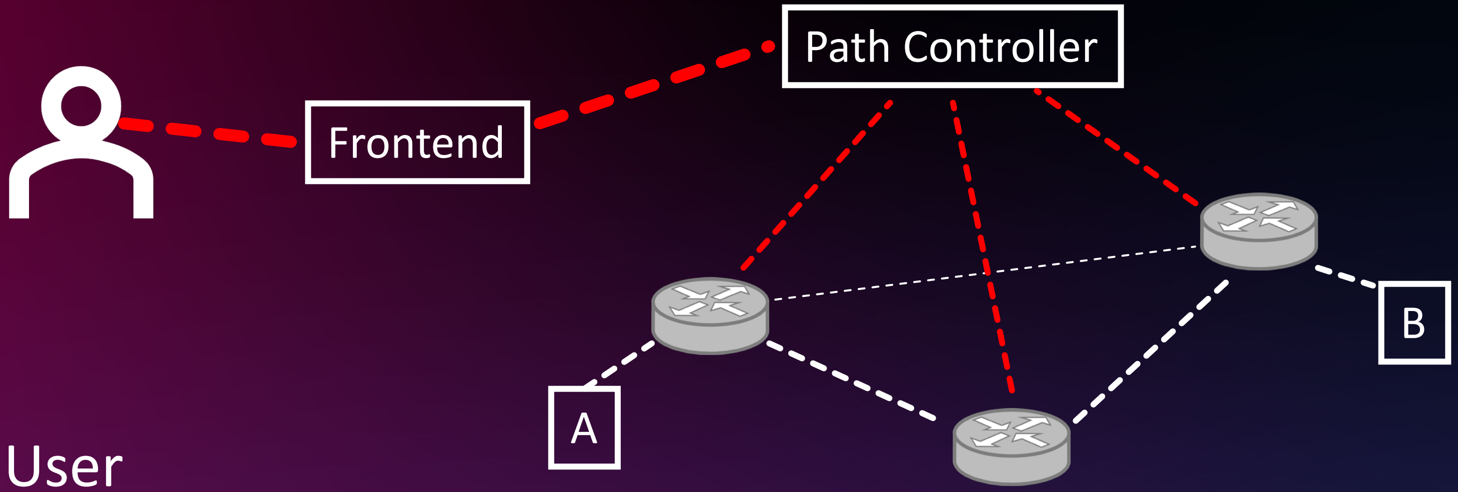

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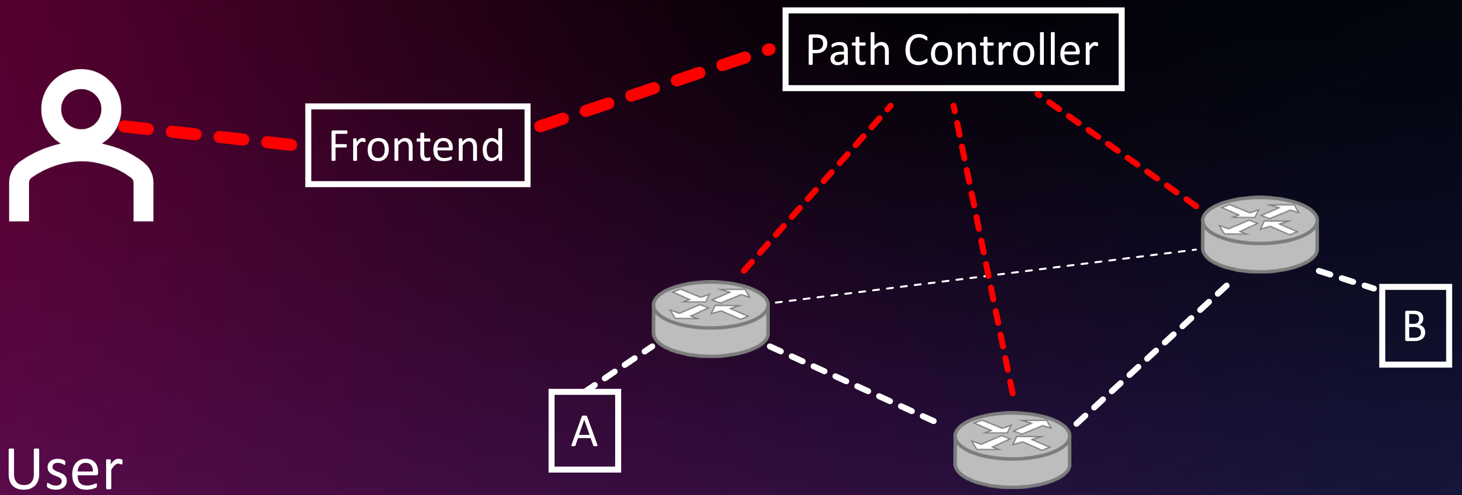

- Increase **transparency** to the User
- **Frontend** Design that includes a Chatbot
- NLU pipelines to better understand user **intents** of path creation

- Promising performance results, but unable to run unsupervised
- Amount of data to train our model

Thank you for your attention

See you at the Ciena booth for a live demo and discussions!

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Human centric approach

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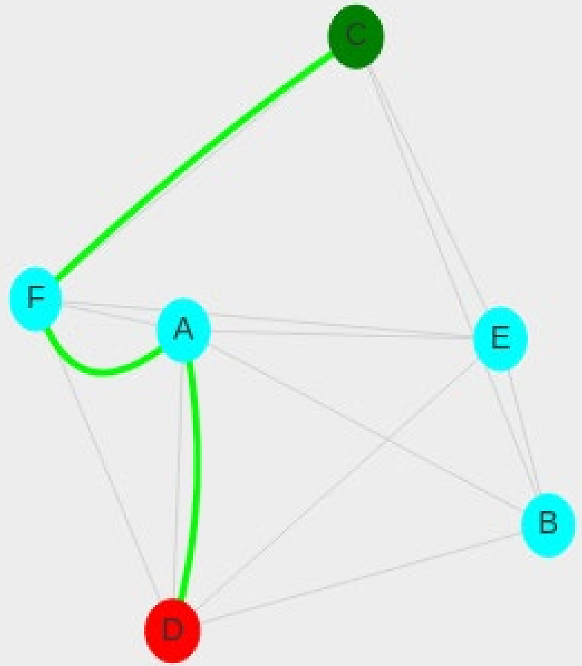
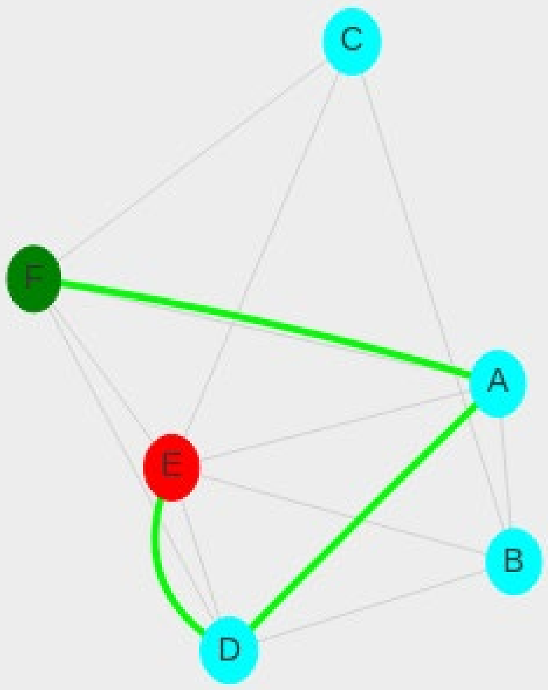


Frontend example

Technical centric approach:

```
define intent create_path:
    from endpoint('F')
    to endpoint('D')
    allow device('A'), vendor('Cisco')
    set bandwidth('min', '100', 'Mbps'), latency('max', '10', 'ms')
    with hops('max','5')
```



Frontend example

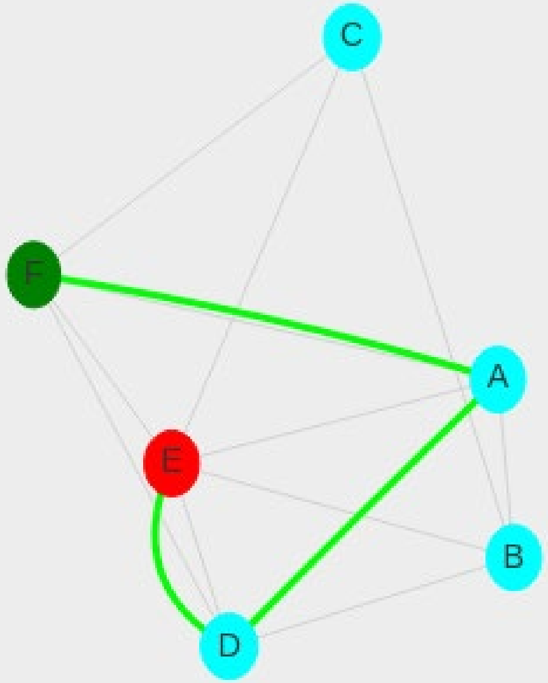
Human centric approach: Chatbot

create a path to D from F via A with at least 100 Mbps bandwidth and max 10 ms latency with Cisco devices within 5 hops

frits

You want to create a path from F to D via A only including devices from Cisco with a limit of 5 hops with a bandwidth greater than 100 Mbps with a latency less than 10 ms

Bot



Intents and Entities

TABLE III
TRAINING DATA AMOUNT FOR THE INTENTS

Intent	**Number of examples**
greet	13
goodbye	10
correct	18
deny	12
create_path	92
bot_challenge	4
reset	9
help	7
more	5
list	6

TABLE IV
TRAINING DATA AMOUNT FOR THE ENTITIES

Entity	**Type**	**Number of examples**
devices	*source*	92
devices	*destination*	92
devices	*excluded_device*	20
devices	*included_device*	20
vendor	*included_vendor*	10
vendor	*excluded_vendor*	10
country	*included_country*	10
country	*excluded_country*	10
limit		10
capacity	*timing*	10
capacity	*size*	10
capacity	*minimal_bandwidth*	10
capacity	*maximum_latency*	10

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A user states the following:

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The ***Intent*** of the user is to create a specific path.

Our model needs to both extract entities, understand their type, and ultimately understand the intent of the user.

- In order to understand the intent of the sentence, in order to understand what to do with the entities, we consider many features of the overall sentence, not looking at entities alone but features surrounding the entities, features of the sentence indicating the intent
- Features allow for a correct classifications of entities.