User-driven Path Control through Intent-Based Networking

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

The Responsible Internet \cite{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 \textbf{black box} to a ‘\textbf{glass box}’

It brings \textbf{Transparency}, \textbf{Controllability} and \textbf{Accountability} to the Internet

\begin{flushright}
\cite{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. \textit{A responsible internet to increase trust in the digital world}. 2020.
\end{flushright}
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
User Intent:
Source: C
Destination: D
Via: A
Max 4 hops
Frontend design

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Destination: D
Via: A
Max 4 hops

Technical centric approach:

```python
define intent create_path:
  from endpoint('C')
  to endpoint('D')
  allow device('A')
  with hops('max', '4')
```
Frontend design

User Intent:
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Human centric approach:
go from C to A to D with max 4 hops
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You want to create a path from C to D via A with a limit of 4 hops
How do we design a chatbot to understand user’s request on path control?

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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

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1. **State intent**
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6. Intent-based feedback

Path properties: Entities

- Devices
  - Source
  - Destination
  - Excluded devices
  - Included devices

- Vendor
  - Excluded vendors
  - Included vendors

- Country
  - Excluded countries
  - Included countries

- Capacity
  - Timing
  - Size
  - Minimal bandwidth
  - Maximum latency

- Hop limit
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Entities

Types of Entities

Hop limit
## Design Considerations

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Required Knowledge</th>
<th>Language</th>
<th>Network</th>
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</thead>
<tbody>
<tr>
<td><strong>Technical centric approach</strong></td>
<td>Unlimited</td>
<td>Network and Syntax</td>
<td>Restricted</td>
<td>UPIN demo</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
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Natural Language Understanding

A user states the following:

“I want to create a path from A to B to C excluding Cisco devices”
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Our model needs to both extract entities, understand their type, and ultimately understand the intent of the user.
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.

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<th>Name</th>
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<tr>
<td>P1 (Baseline)</td>
<td>WhitespaceTokenizer, RegexFeaturizer, DIETClassifier, EntitySynonymMapper,</td>
</tr>
<tr>
<td></td>
<td>ResponseSelector, FallbackClassifier</td>
</tr>
<tr>
<td>P2</td>
<td>P1 + CountVectorsFeaturizer</td>
</tr>
<tr>
<td>P3</td>
<td>P1 + LexicalSyntacticFeaturizer</td>
</tr>
<tr>
<td>P4</td>
<td>P1 + CountVectorsFeaturizer + LexicalSyntacticFeaturizer</td>
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Natural Language Understanding Pipelines

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</tr>
<tr>
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</table>

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.

<table>
<thead>
<tr>
<th>CountVectorsFeaturizer</th>
<th>LexicalSyntacticFeaturizer</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="CountVectors" /></td>
<td><img src="image2" alt="LexicalSyntactic" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>&quot;From&quot;, &quot;A&quot;, &quot;to&quot;, &quot;B&quot;, &quot;to&quot;, &quot;C&quot;</th>
<th><img src="image3" alt="LexicalSyntactic" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

```
TableRow: CountVectorsFeaturizer
Title: "From", "A", "to", "B", "to", "C"
Column: "From", "A", "to", "B", "C"
Values: 1, 1, 2, 1, 1
```

```
TableRow: LexicalSyntacticFeaturizer
Title: "excluding", "Cisco", "devices"
Column: "excluding", "Cisco", "devices"
Values: 0, 1, 0
```

```
TableRow: LexicalSyntacticFeaturizer
Title: suffix3
Column: suffix3, "sco", "ces"
Values: "ing", "sco", "ces"
```

```
TableRow: LexicalSyntacticFeaturizer
Title: prefix2
Column: prefix2, "Cl", "de"
Values: "ex", "Cl", "de"
```
Performance metrics

\[
\text{accuracy} = \frac{TP + TN}{TP + TN + FP + FN}
\]

\[
\text{precision} = \frac{TP}{TP + FP}
\]

\[
\text{recall} = \frac{TP}{TP + FN}
\]

\[
F1 = \frac{2 \cdot (\text{precision} \cdot \text{recall})}{\text{precision} + \text{recall}}
\]

- \(TP\) = true positives
- \(FP\) = false positives
- \(TN\) = true negatives
- \(FN\) = false negatives
### Performance Results

<table>
<thead>
<tr>
<th></th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy intent</strong></td>
<td>0.63</td>
<td>0.84</td>
<td>0.83</td>
<td>0.85</td>
</tr>
<tr>
<td><strong>Precision intent</strong></td>
<td>0.63</td>
<td>0.86</td>
<td>0.83</td>
<td>0.86</td>
</tr>
<tr>
<td><strong>Recall intent</strong></td>
<td>0.63</td>
<td>0.84</td>
<td>0.83</td>
<td>0.85</td>
</tr>
<tr>
<td><strong>F1 score intent</strong></td>
<td>0.63</td>
<td>0.83</td>
<td>0.83</td>
<td>0.85</td>
</tr>
<tr>
<td><strong>Accuracy entity</strong></td>
<td>0.74</td>
<td>0.82</td>
<td>0.93</td>
<td>0.93</td>
</tr>
<tr>
<td><strong>Precision entity</strong></td>
<td>0.33</td>
<td>0.46</td>
<td>0.85</td>
<td>0.83</td>
</tr>
<tr>
<td><strong>Recall entity</strong></td>
<td>0.29</td>
<td>0.46</td>
<td>0.80</td>
<td>0.80</td>
</tr>
<tr>
<td><strong>F1 score entity</strong></td>
<td>0.31</td>
<td>0.46</td>
<td>0.82</td>
<td>0.82</td>
</tr>
</tbody>
</table>
Takeaway

- Increase **transparency** to the User
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- **Frontend** Design that includes a Chatbot
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• NLU pipelines to better understand user **intents** of path creation
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- Promising performance results, but unable to run unsupervised
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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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Frontend design

Technical centric approach

Human centric approach

declare intent create_path:
from endpoint('C')
to endpoint('D')
allow device('A')
with hops('max',4')

go from C to A to D with max 4 hops

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

```python
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

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
# Intents and Entities

## TABLE III
**Training data amount for the intents**

<table>
<thead>
<tr>
<th>Intent</th>
<th>Number of examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>greet</td>
<td>13</td>
</tr>
<tr>
<td>goodbye</td>
<td>10</td>
</tr>
<tr>
<td>correct</td>
<td>18</td>
</tr>
<tr>
<td>deny</td>
<td>12</td>
</tr>
<tr>
<td>create_path</td>
<td>92</td>
</tr>
<tr>
<td>bot_challenge</td>
<td>4</td>
</tr>
<tr>
<td>reset</td>
<td>9</td>
</tr>
<tr>
<td>help</td>
<td>7</td>
</tr>
<tr>
<td>more</td>
<td>5</td>
</tr>
<tr>
<td>list</td>
<td>6</td>
</tr>
</tbody>
</table>

## TABLE IV
**Training data amount for the entities**

<table>
<thead>
<tr>
<th>Entity</th>
<th>Type</th>
<th>Number of examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>devices</td>
<td>source</td>
<td>92</td>
</tr>
<tr>
<td>devices</td>
<td>destination</td>
<td>92</td>
</tr>
<tr>
<td>devices</td>
<td>excluded_device</td>
<td>20</td>
</tr>
<tr>
<td>devices</td>
<td>included_device</td>
<td>20</td>
</tr>
<tr>
<td>vendor</td>
<td>included_vendor</td>
<td>10</td>
</tr>
<tr>
<td>vendor</td>
<td>excluded_vendor</td>
<td>10</td>
</tr>
<tr>
<td>country</td>
<td>included_country</td>
<td>10</td>
</tr>
<tr>
<td>country</td>
<td>excluded_country</td>
<td>10</td>
</tr>
<tr>
<td>limit</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>capacity</td>
<td>timing</td>
<td>10</td>
</tr>
<tr>
<td>capacity</td>
<td>size</td>
<td>10</td>
</tr>
<tr>
<td>capacity</td>
<td>minimal_bandwidth</td>
<td>10</td>
</tr>
<tr>
<td>capacity</td>
<td>maximum_latency</td>
<td>10</td>
</tr>
</tbody>
</table>
A user states the following:

“I want to create a path from A to B to C excluding Cisco devices”

A, B, C, Cisco are Entities (A, B and C are devices, Cisco is a Vendor)

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.