Exploiting AI-planning and NLP for Achieving Autonomous Network Reconfiguration

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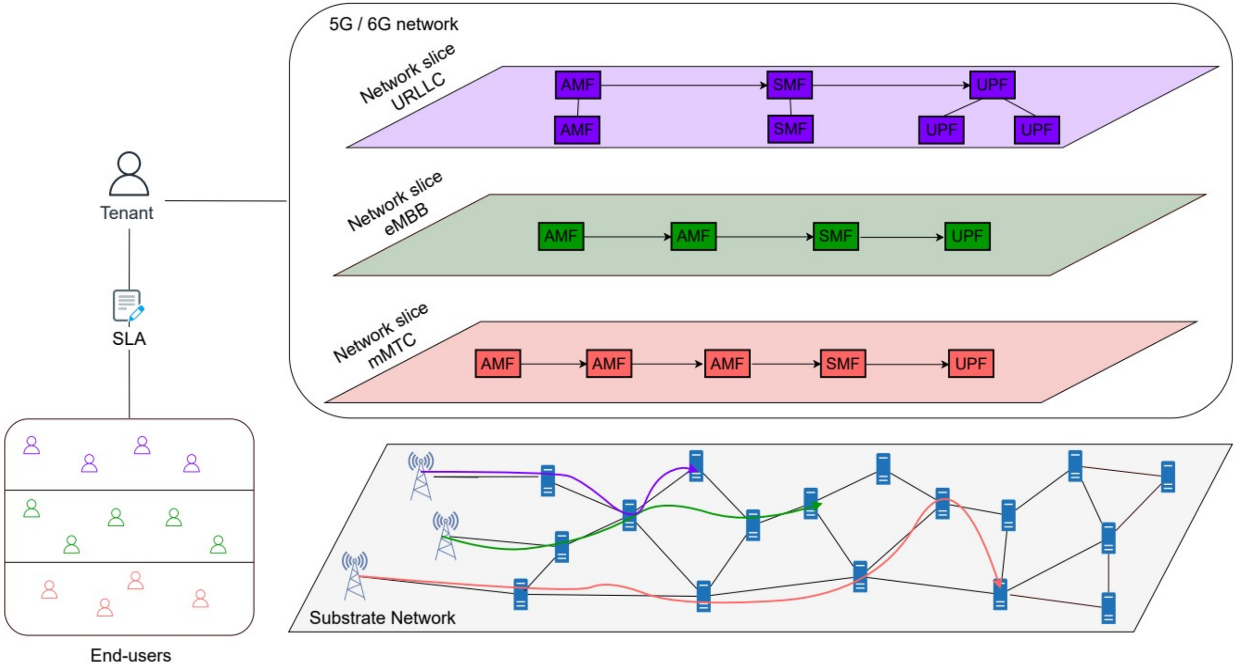
Outline

- Problem
- ATRAP
- NORA

Problem



RECONFIGURING NETWORK SLICES FROM THE TENANT-SIDE

- No in-depth knowledge on substrate network
- No prior knowledge on network configurations commands
- Minimal dependance on InP → Timely reconfigurations
- Avoid service disruption → Respect SLAs

Problem

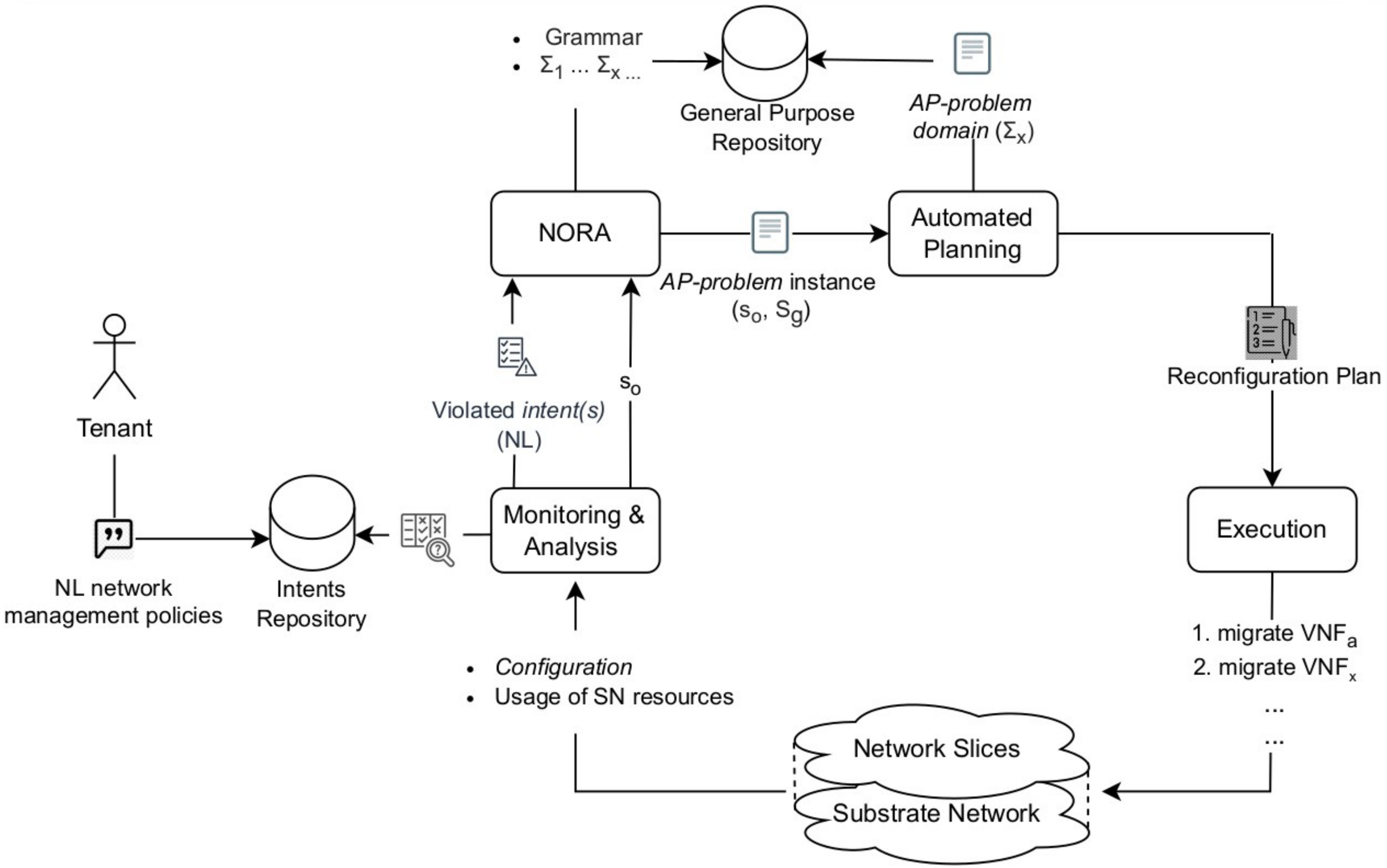
Given an undesired network state (s_o), how to compute reconfiguration management actions on-the-fly to turn the network into a desired state (S_g)?

- How to include the automated planning (AP) technique as decision maker for network reconfiguration?

- Can the AP based decision making for network reconfiguration be guided by high-level network management policies (*intents*)?

ATRAP

- An approach based on the monitor-analyze-plan-execute-knowledge method (MAPE-K loop) and AP for computing 5G/6G network reconfiguration plans autonomously.



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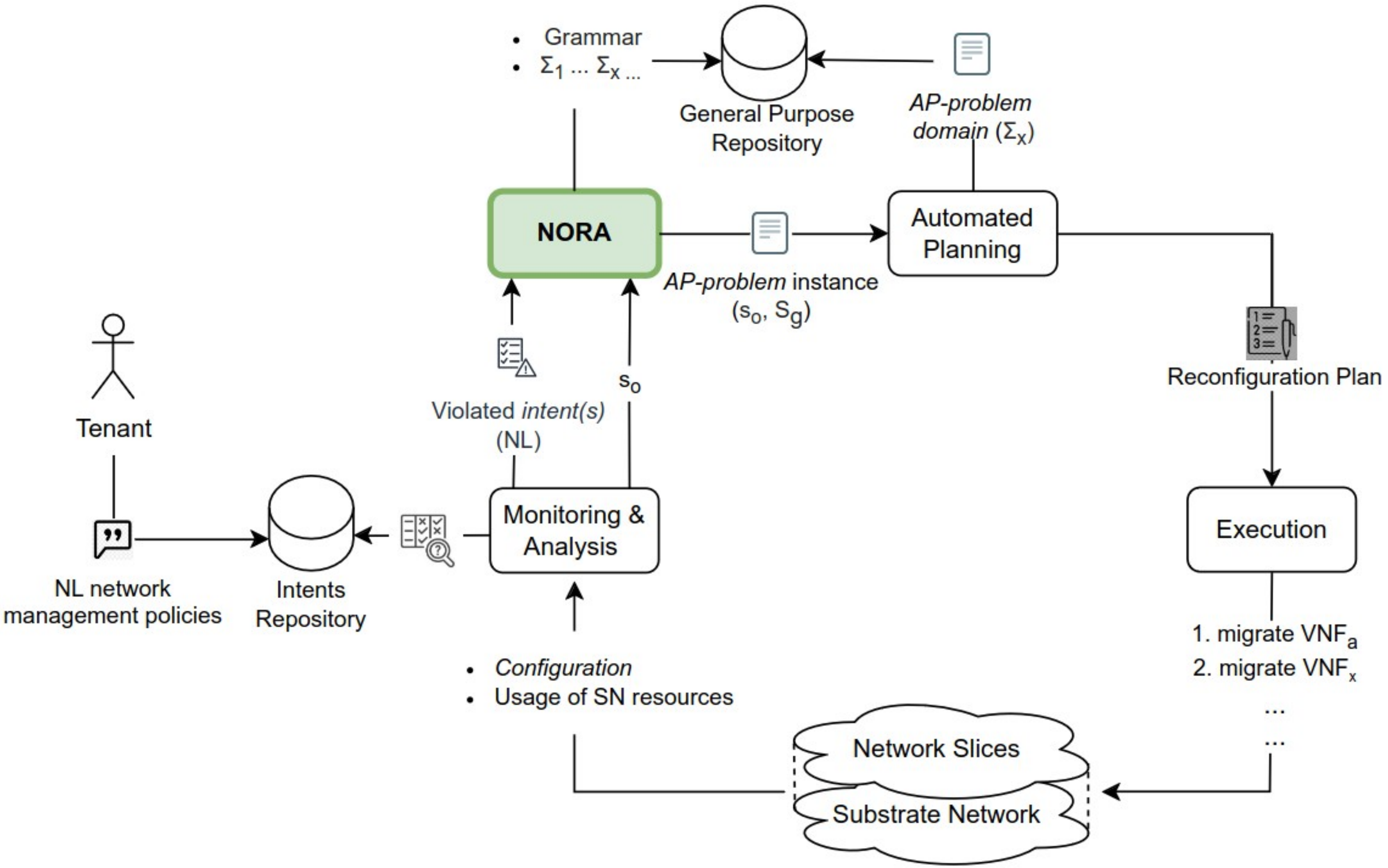
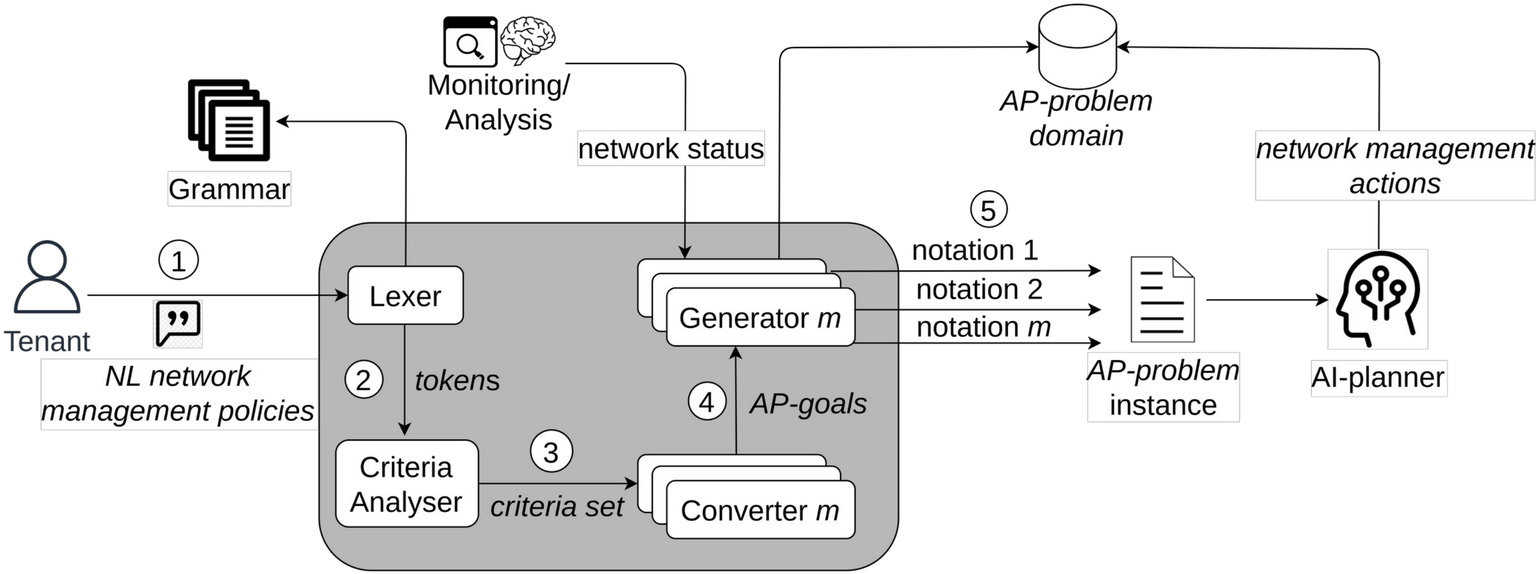


NORA

- NORA transforms network management policies expressed by the network slice tenants in pure natural language (NL) into the goals of an AP-problem (AP-goals) by using Natural Language Processing (NLP).

- NORA combines such AP-goals with both, the current network status and available reconfiguration actions (Σ), to come up with a reconfiguration plan that turns the network from a source -undesired- configuration (s_o) into a target configuration (S_g).

NORA - Architecture



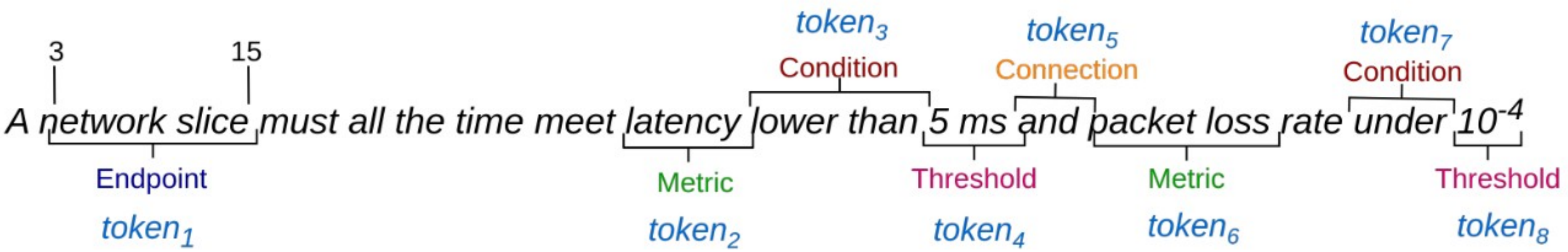
NORA - Lexer

- Extracts representative terms for the network management domain (*tokens*) from input policy (*P*)

P = < Target (service / endpoint), Metric, Condition, Threshold >

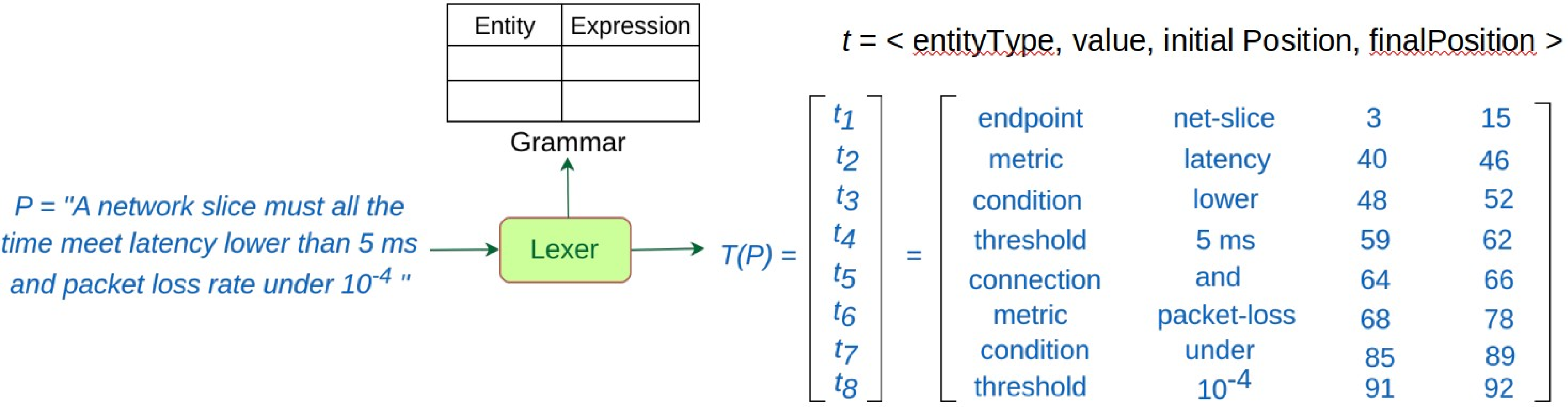
Entity	Expression
Service	VoIP, Streaming, HTTP, FTP, SMTP, P2P...
Endpoint	network slice, host node, gateway, database, VM, client, user...
Metric	bandwidth, CPU, delay, packet loss, throughput, jitter, load, latency...
Condition	more, high, higher, up, over, exceed, not under,...
	equal, like, even, same, similar...
	less, lower, not exceed, down, below, under...
Threshold-unit	ms, s, kbps, GB, GHz, %...
Connection	and, also, as well as, or...

Network management domain grammar



NORA - Lexer

- Creates a *T-matrix* where each row is a *token* extracted from *P*



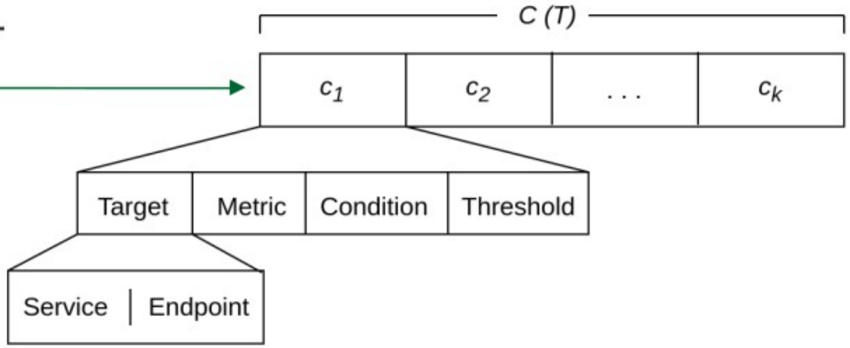
NORA – Criteria Analyser

- Compares tokens positions (rows of *T(P)*) to associate them as different atomic criteria ($c_1 \dots c_k$).

Algorithm 1: Tokens Positions Comparison

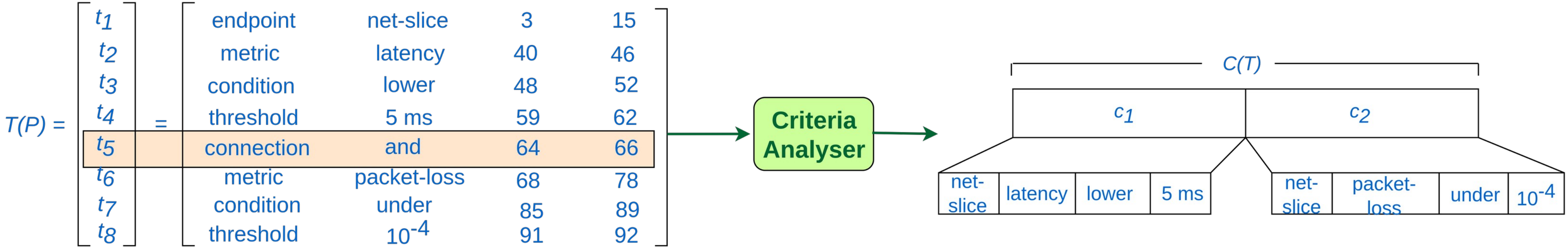
Input: T: Matrix of tokens.
Output: $C = [c_1, c_2 \dots c_k]$: Granular Goals Collection.

con = tokens type Connection in T;
$k = con + 1$;
$C = [c_1, c_2 \dots c_k]$;
for *each c in C* **do**
  Search in T the token of type *endpoint* or *service* with the minor initialPosition number;
  c.append(endpoint | service.value);
  Search in T the closest token of type *metric*;
  c.append(metric.value);
  Search in T the closest token of type *condition*;
  c.append(constraint.value);
  Search in T the closest token of type *threshold* ;
  c.append(*threshold*.value);
  Mark in T all already appended tokens
end



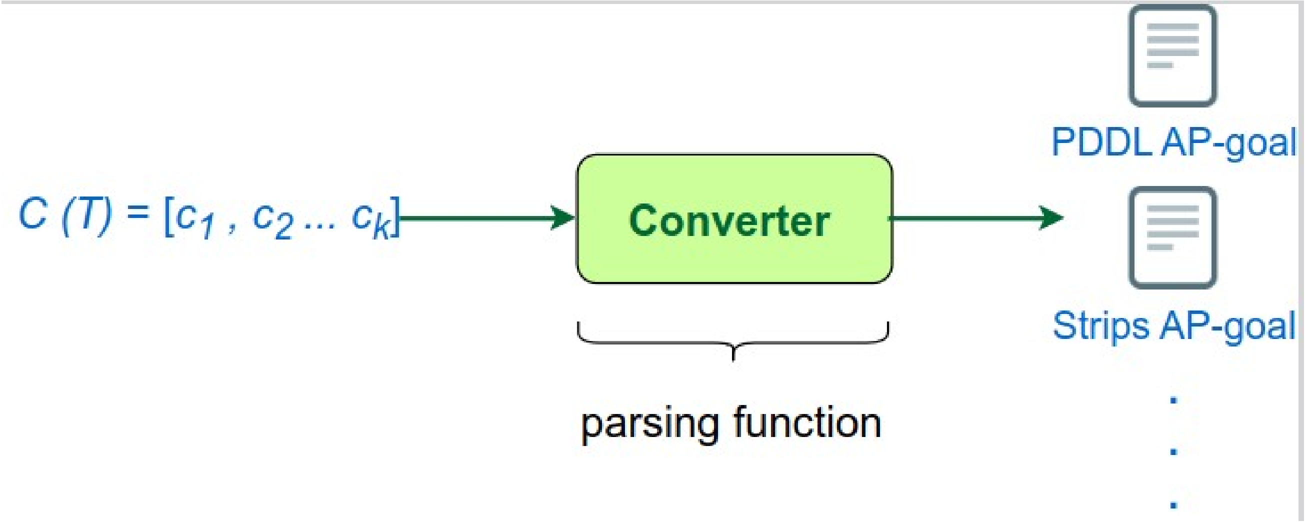
NORA – Criteria Analyser

- Forms a criteria set (*C*) from previous matrix T, *i.e.*, *C(T)*



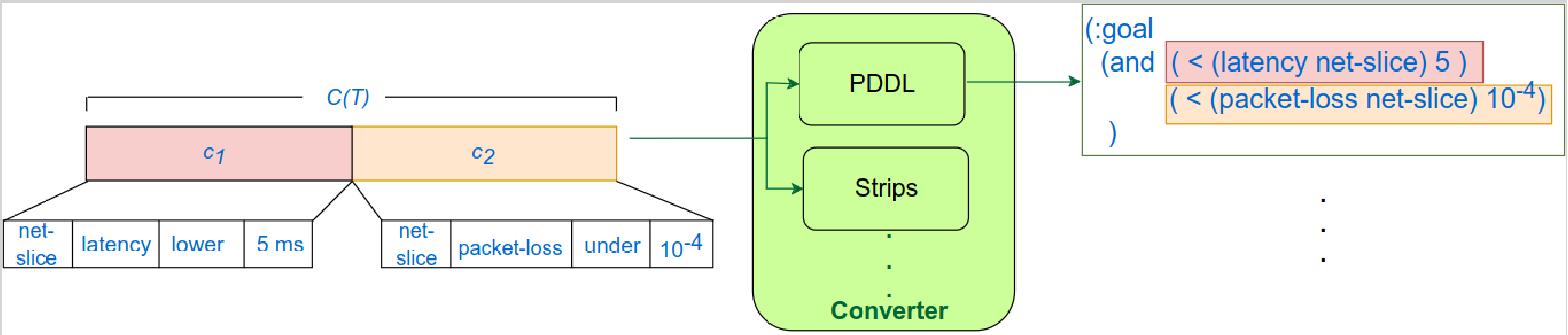
NORA – Converter

- Parses the elements of *C* to a target *AP-goal* notation.



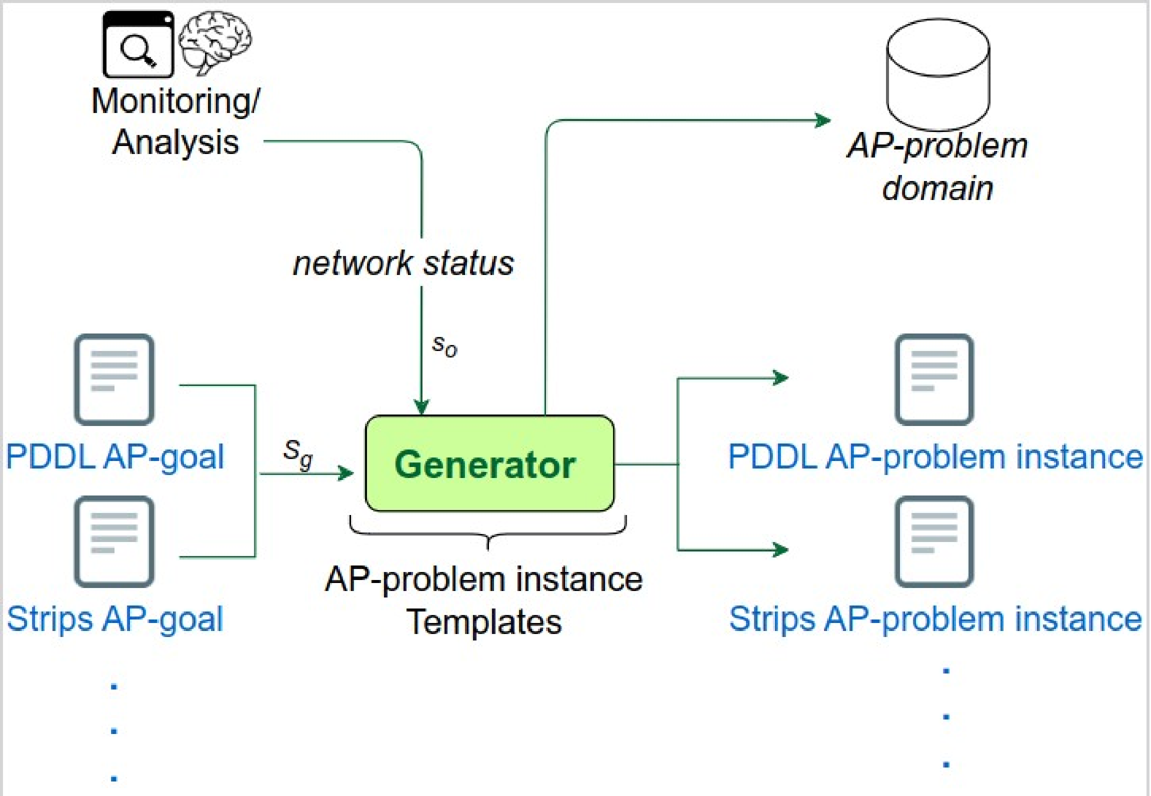
NORA – Converter

- Selects from *m* parsing functions to come up with the AP-goal that represents the target network status (S_g)



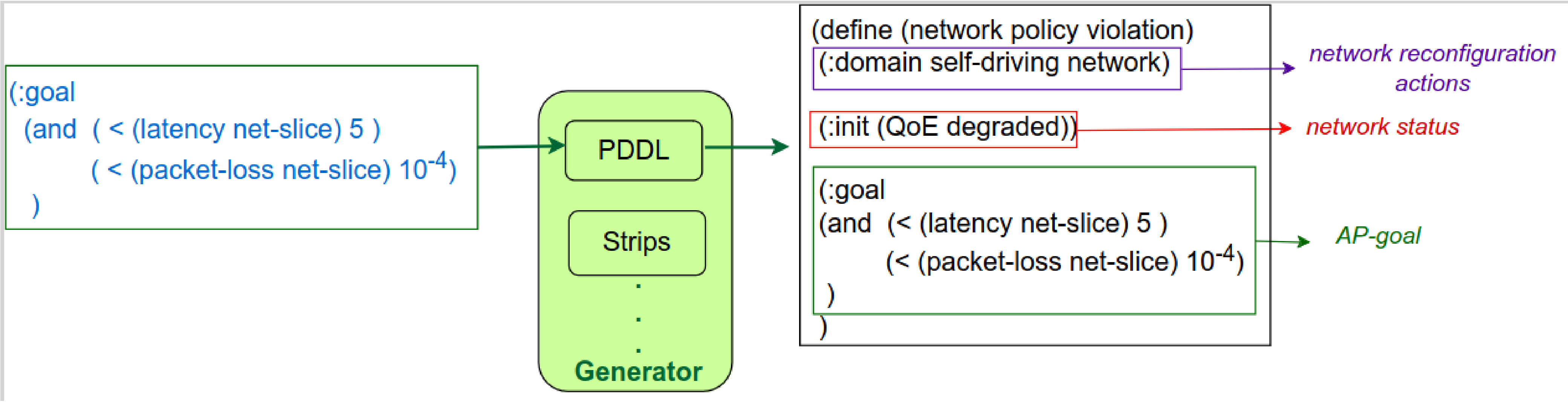
NORA – Generator

- Builds up an *AP-problem* instance in a target AP notation

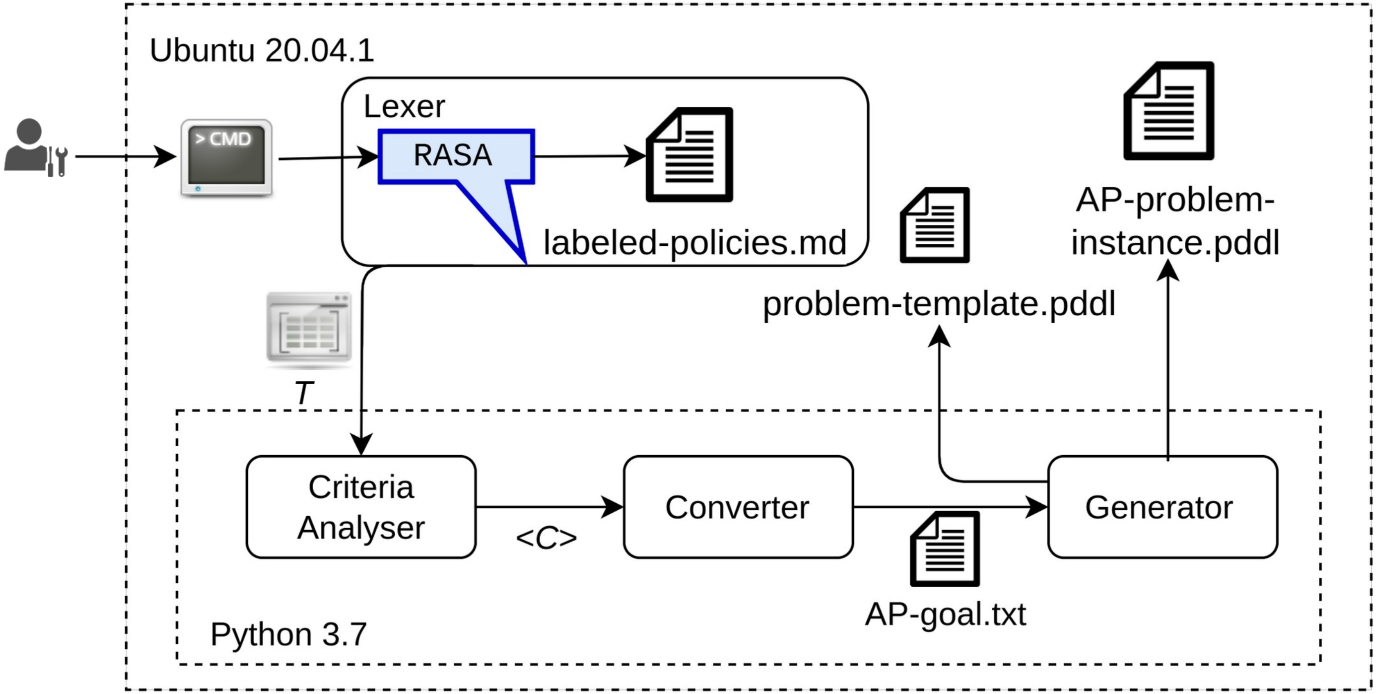


NORA – Generator

- Template filling



NORA – Evaluation



NORA – Evaluation

- 250 NL network management policies were collected from 20 researchers.
- Representative network management terms of each policy were labeled with its corresponding entity type

Entity	Expression
Service	VoIP, Streaming, HTTP, FTP, SMTP, P2P...
Endpoint	network slice, host node, gateway, database, VM, client, user...
Metric	bandwidth, CPU, delay, packet loss, throughput, jitter, load, latency...
Condition	more, high, higher, up, over, exceed, not under,...
	equal, like, even, same, similar...
	less, lower, not exceed, down, below, under...
Threshold-unit	ms, s, kbps, GB, GHz, %...
Connection	and, also, as well as, or...

Network management domain grammar

```
## intent:policies

- A [network slice](endpoint) must all the time meet [latency](metric) [lower than](condition) [5 ms](threshold) and
[packet loss](metric) rate [under](condition) [10-4](threshold)

- No [node](endpoint) in the substrate can be occupied in [more than](condition) [60%](threshold) of its [total capacity](metric)
```

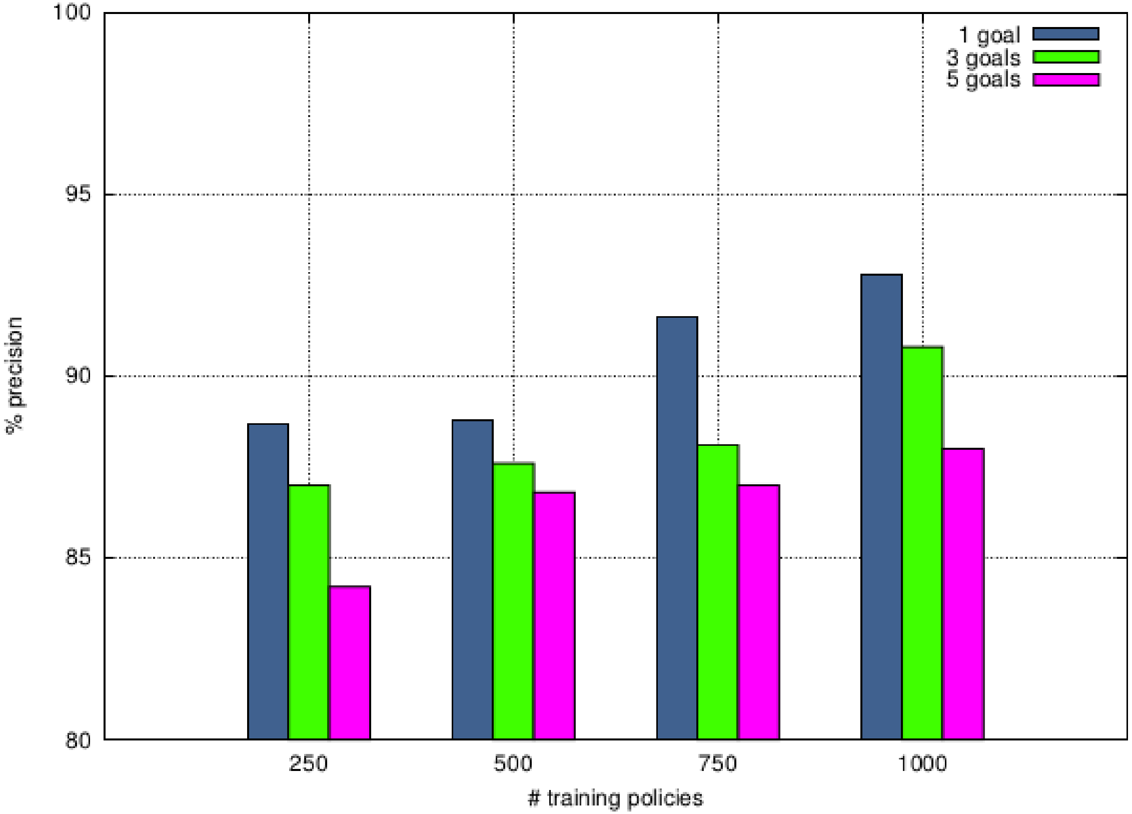
NORA – Evaluation

- 1000 NL network management policies generated and labeled from random combinations of terms contained in the grammar + expressions as “NORA, the network must…” (base corpus)
- Cross-validation to tune up the Lexer
- *P* = ”A network slice must all the time meet latency lower than 5 ms and packet loss rate under 10^{-4}


```
"project": "NORA"
ENTITIES
    {
        "end": 15,
        "entity": "endpoint",
        "extractor": "Mitie",
        "start": 3,
        "value": "network slice"
    },
    {
        "end": 46,
        "entity": "metric",
        "extractor": "Mitie",
        "start": 40,
        "value": "latency"
    },
    {
        "end": 52,
        "entity": "condition",
        "extractor": "Mitie",
        "start": 48,
        "value": "lower than"
    },
    {
        "end": 62,
        "entity": "threshold",
        "extractor": "Mitie",
        "start": 59,
        "value": "5 ms"
    },
    ...
]
```

NORA – Evaluation

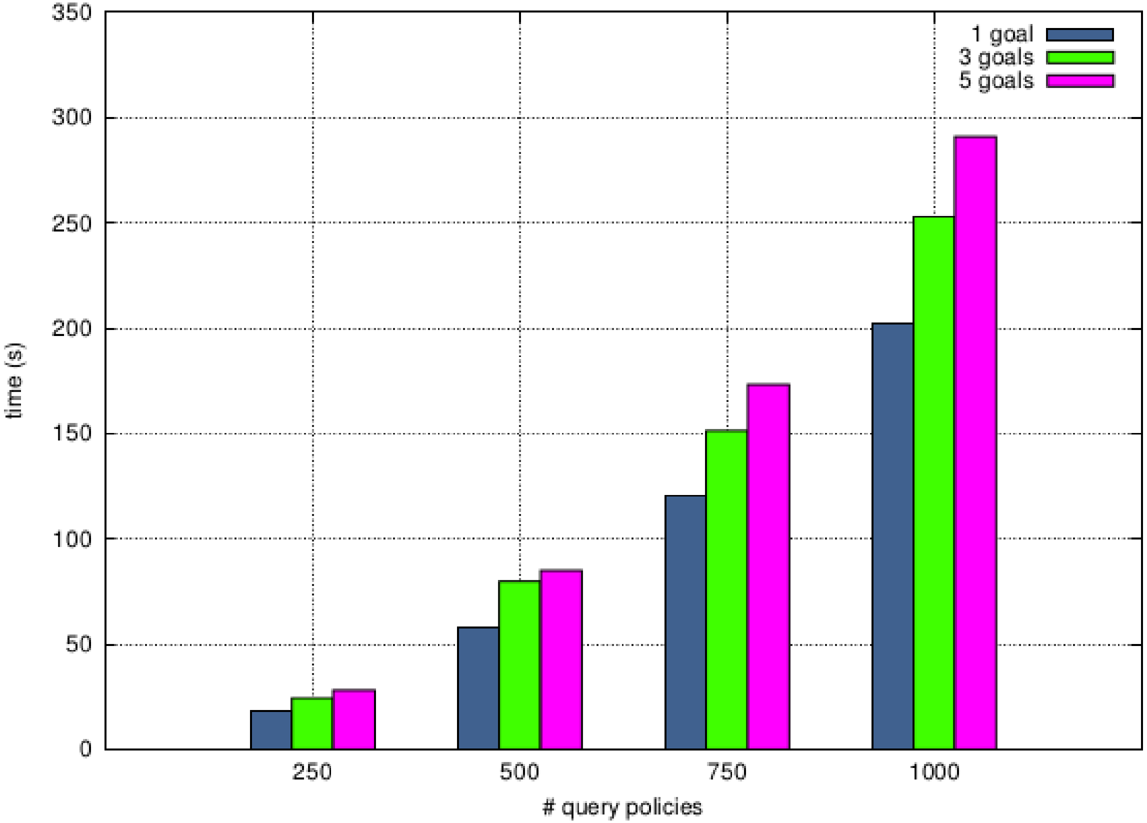
- Precision vs. Training Policies



- NORA's precision oscillates between 84% and 93%
- In the collected policies, less than 5% involved 5 atomic goals.
- Enriching grammar will improve precision ---> **LLM!**

NORA – Evaluation

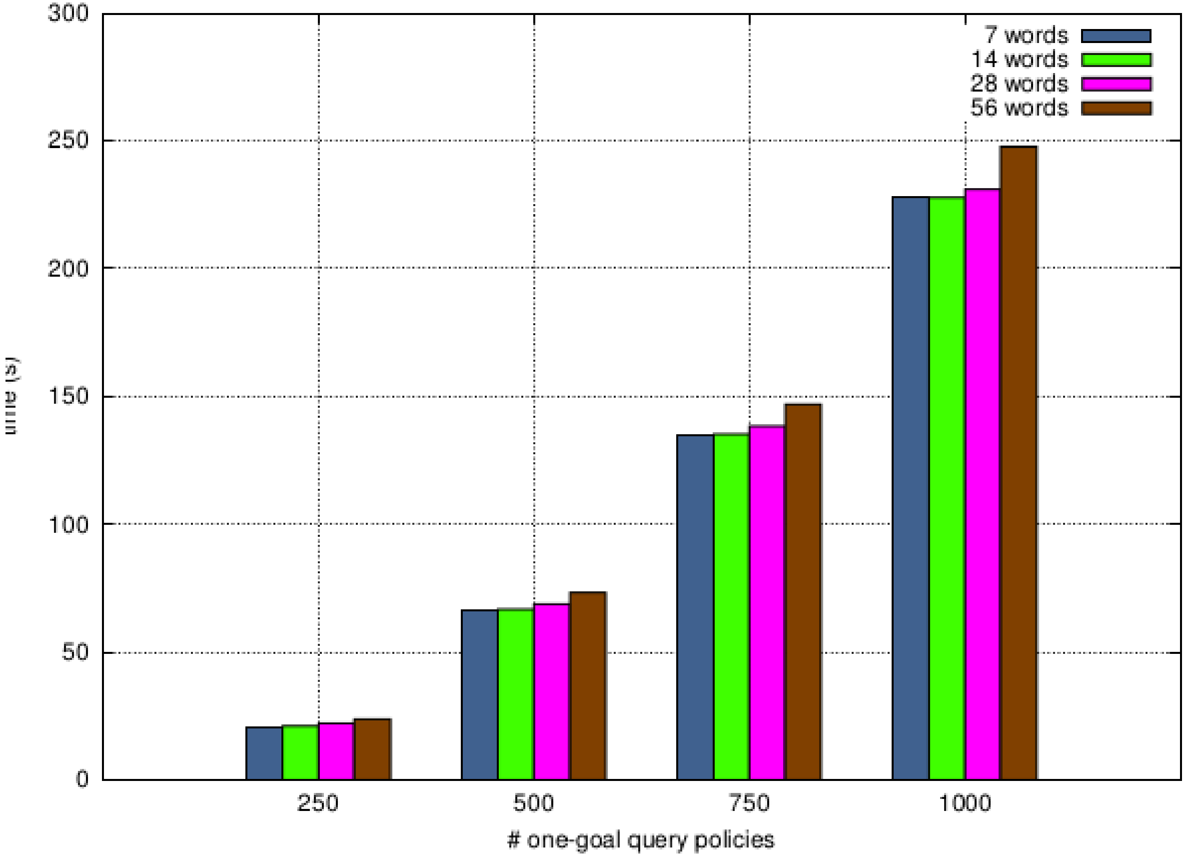
- End-to-end processing time by atomic goals



- NORA's processing time depends on the number of granular goals involved in the input policy.

NORA – Evaluation

- End-to-end processing time by policy length



- The number of words contained in a policy sentence does not influence processing time.

References

- Angela Rodriguez-Vivas, Oscar Mauricio Caicedo, Armando Ordoñez, Lisandro Z. Graville and Jéferson Campos Nobre. "Bridging the Gap Between Network Management and Artificial Intelligence: A Natural Language Policies Translator" Extended Abstract and Poster. Latin America Students Workshop (LANCOMM19). Brazilian Symposium on Computer Networks and Distributed Systems (SBRC2019), May 7th, 2019, Gramado – Brazil.

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Policies Dataset: https://github.com/arodriguezvivas10/GoalPolicies

ATRAP PDDL AP-problems: https://github.com/arodriguezvivas10/ATRAP-AP-problems

Thank you!

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