– A Case Study [9] –

A fairy tale

(pictures from Matteo Garrone's "Pinocchio")

Tell them...

A fairy tale

(pictures from Matteo Garrone's "Pinocchio")

and they'll behave

A fairy tale

(pictures from Matteo Garrone's "Pinocchio")

unless they don't

A fairy tale

(pictures from Matteo Garrone's "Pinocchio")

So, keep an eye on'em

A fairy tale

(pictures from Matteo Garrone's "Pinocchio")

of course, it's for their own good

At a glance

API-based development

- difficult in theory...
- ...and in practice

Behavioural specifications (of API)

- help in
  - documenting
  - monitoring
- Case study: OpenDXL

Open Data Exchange Layer

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Introduction to OpenDXL

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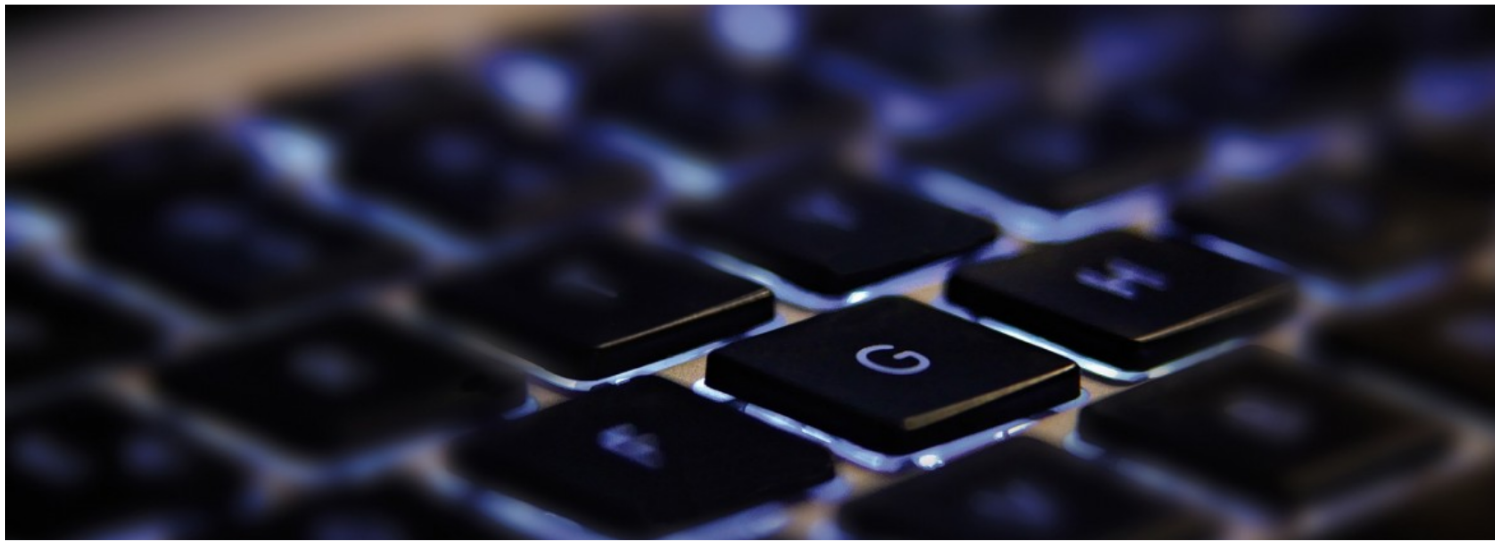
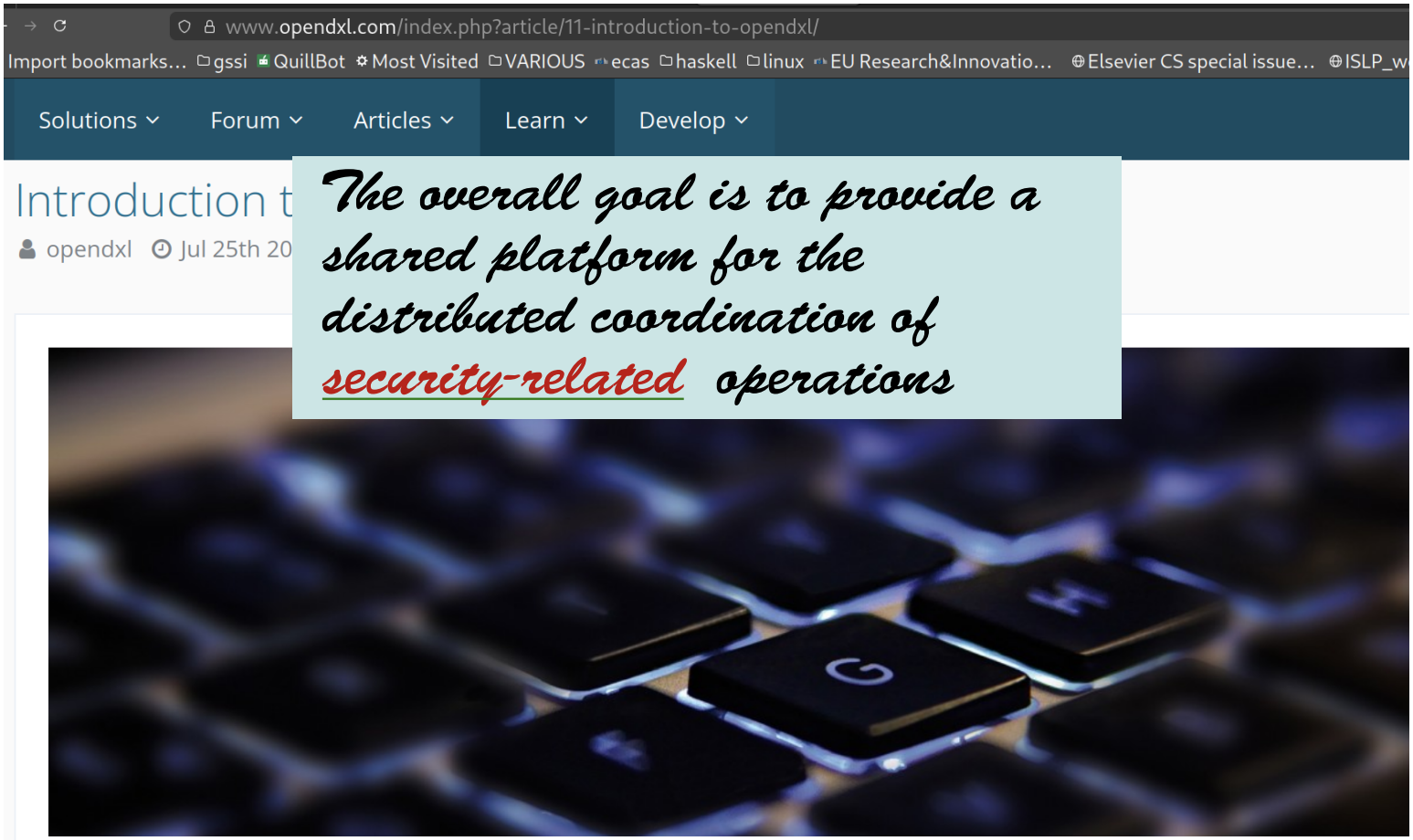
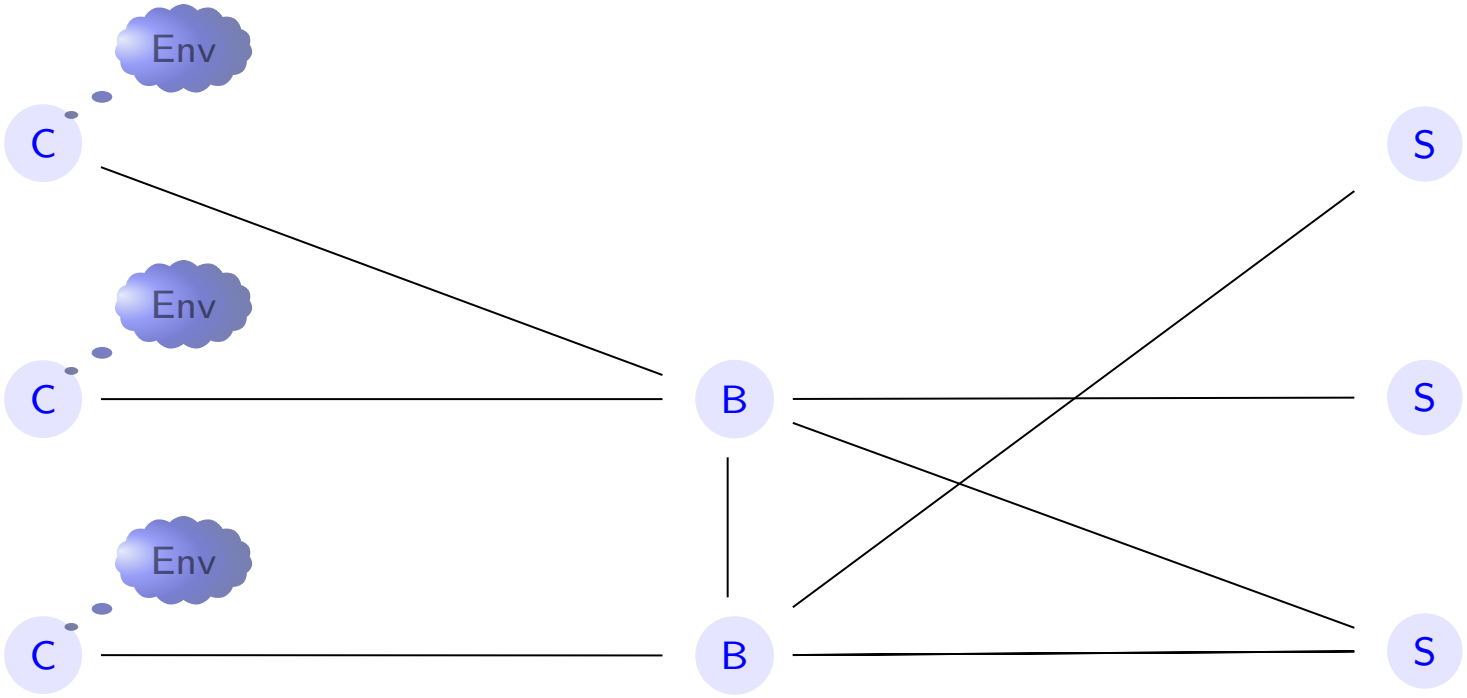


The goal of the Open Data Exchange Layer (OpenDXL) is to enable security devices to share intelligence and orchestrate security operations in real time.

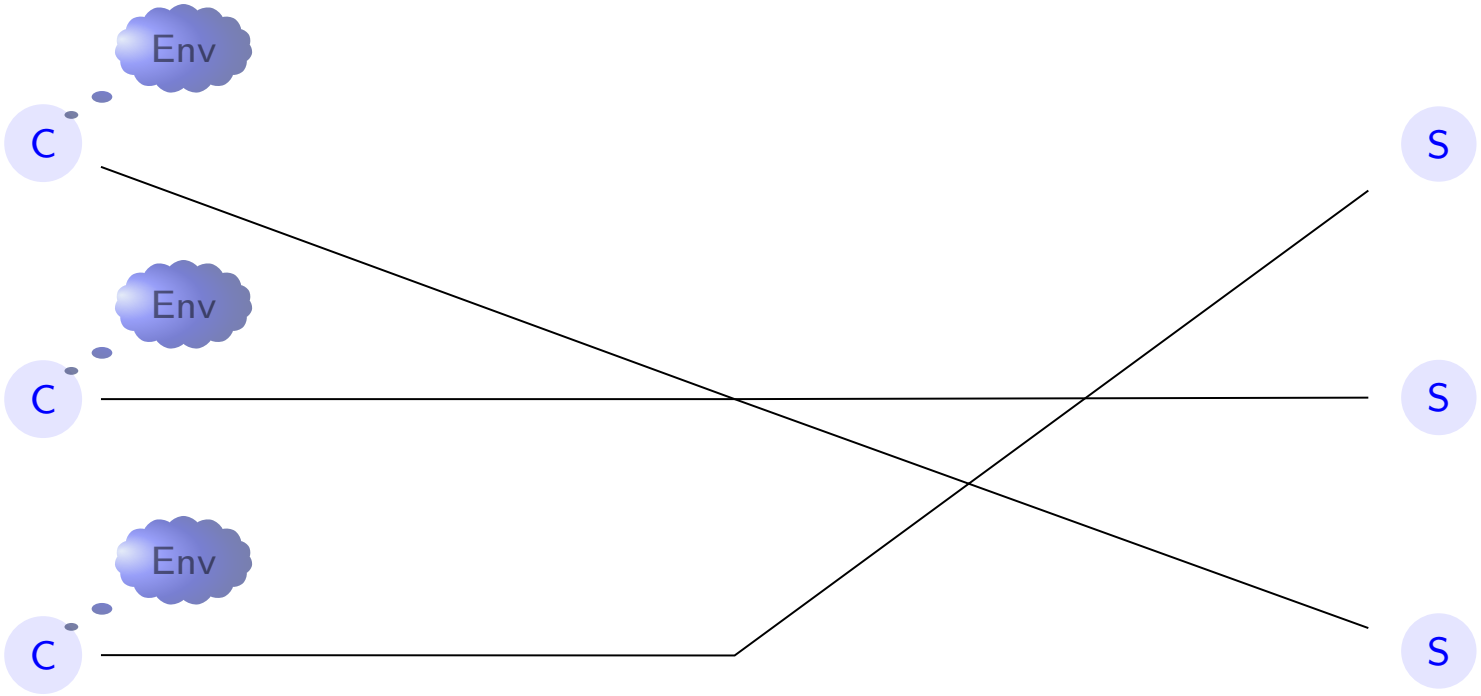
Open Data Exchange Layer



Architecture of OpenDXL



Architecture of OpenDXL

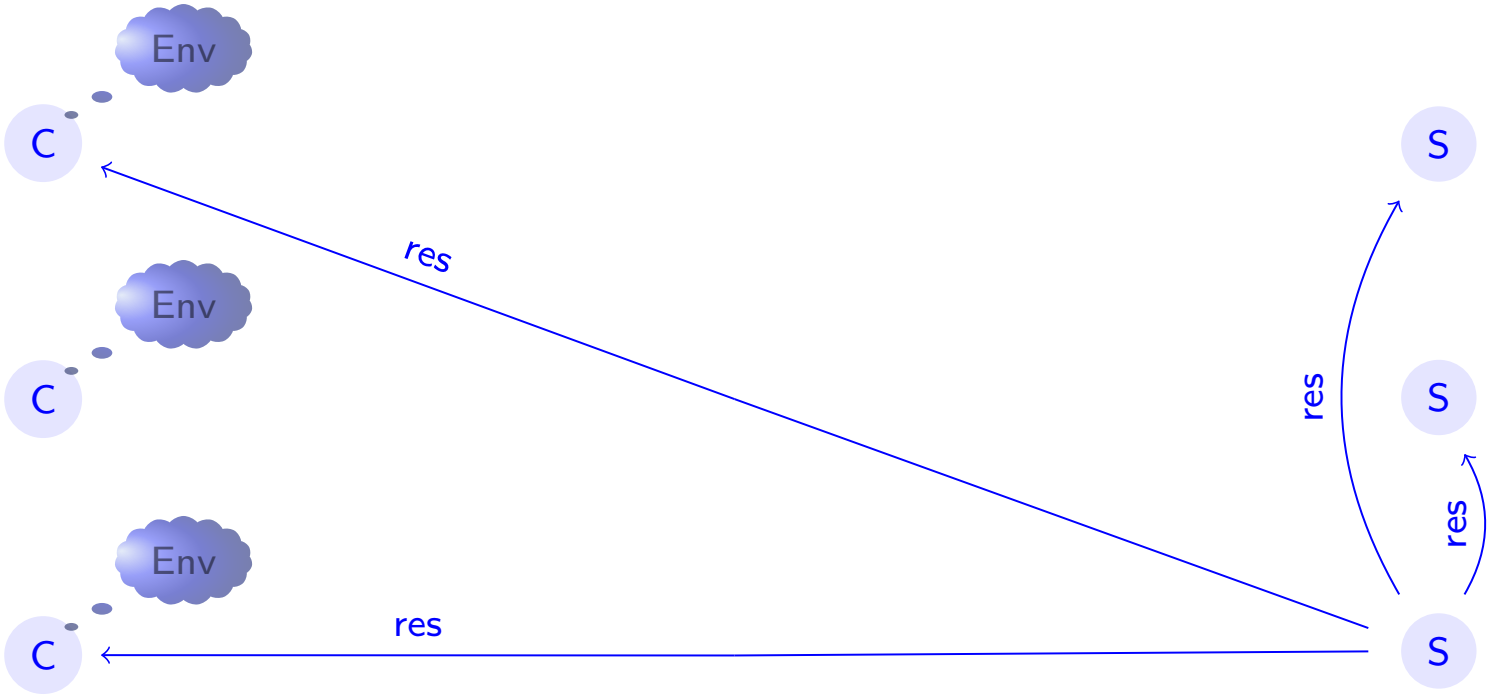


- Brokers abstracted away

Architecture of OpenDXL

- Brokers abstracted away
- Event-based communication

Architecture of OpenDXL



- Brokers abstracted away
- Event-based communication
- Application-level protocols are necessary

Threat Intelligence Exchange service

Threat Intelligence Exchange service

- OpenDXL's nature is service-oriented

Threat Intelligence Exchange service

- OpenDXL's nature is service-oriented

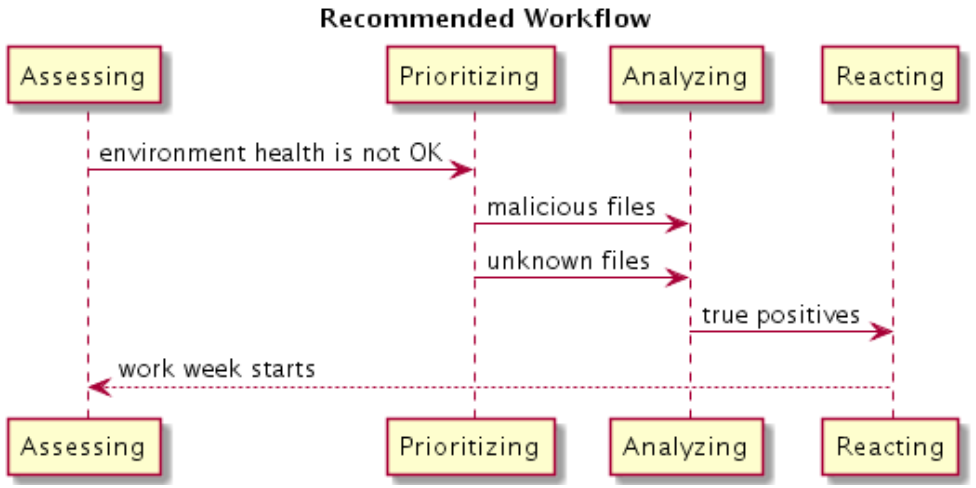
TIE's features

coordination of activities involving

- assessment of the security threats
  of configuration files, certificates, unsigned or unknown files, etc.
- prioritisation of analysis steps
  focusing on malicious or unknown files
- customisation of security queries
  based on reputation-based data such as product or company names
- reaction to suspicious indicators

Documenting TIE

Semi-formal diagrams



Verbal recommendations

a client "must have permission to send messages to the `/mcafee/service/tie/reputation/set` topic"

Sounds good...in theory

In practice

- "Stuff" developed @McAfee works fine
  - McAfee provides the service
  - and clients
- but it's a SOA: 3rd-party clients misbehave sometimes
- hence, defensive programming of TIE services

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In practice

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Caveat

3rd-party code may not be available for analysis
Hence, post-mortem analysis of execution logs to identify misbehaviour and communicate it to 3rd-parties

Idea

Adding more precision:

1. draw the protocol (global choreography)
2. turn the "drawing" into a behavioural type
3. project to component specs (local types)
4. turn local specs into state machines

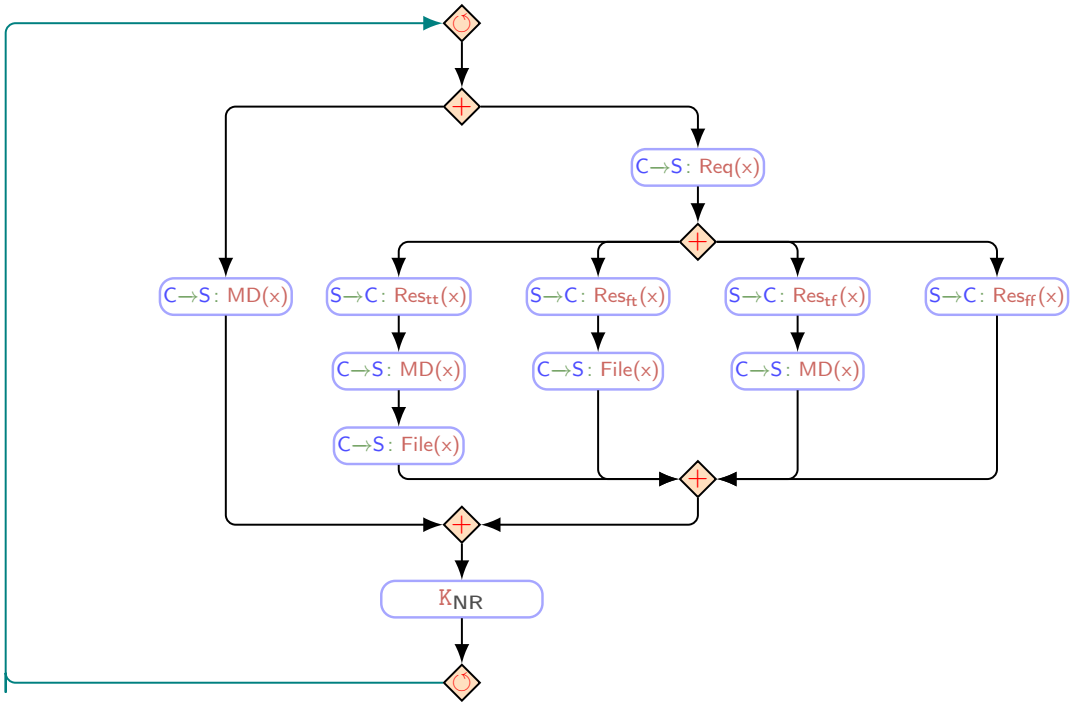
Advantages

- global choreographies: formal & precise, yet intuitive
- algorithmically generate monitors
- enhance "program comprehension"

Let's tie our TIE

No Greek letters or esoteric symbols were used in the making of this global view

After a couple of meetings...



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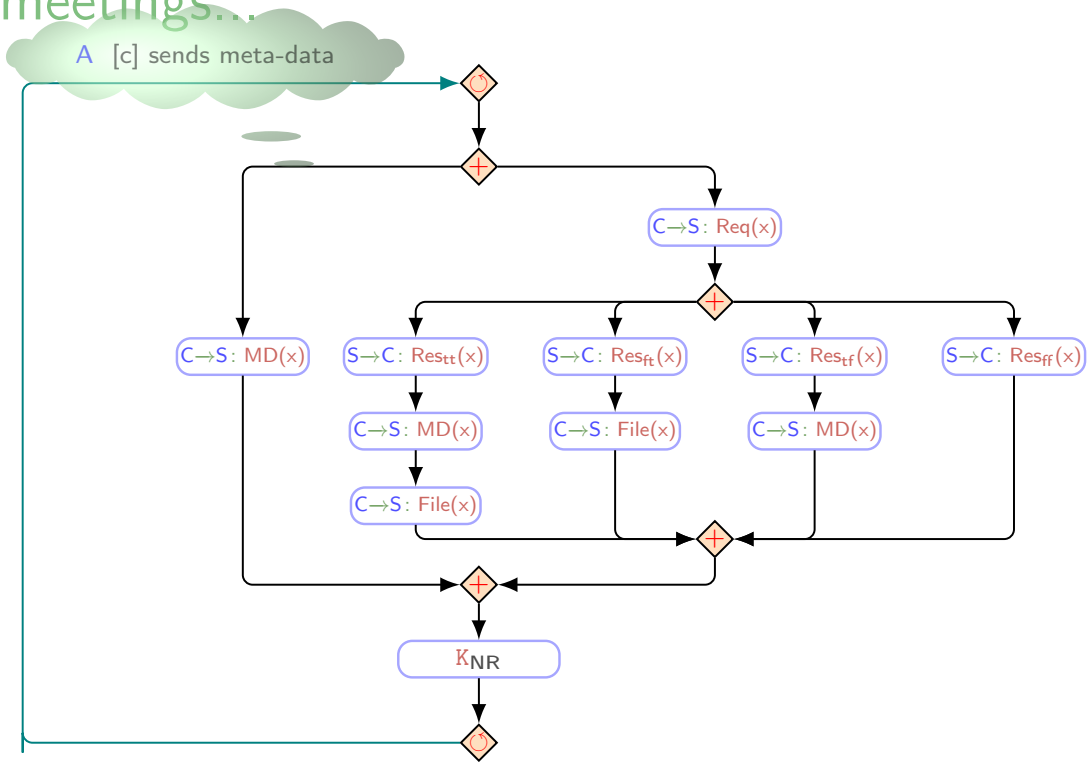

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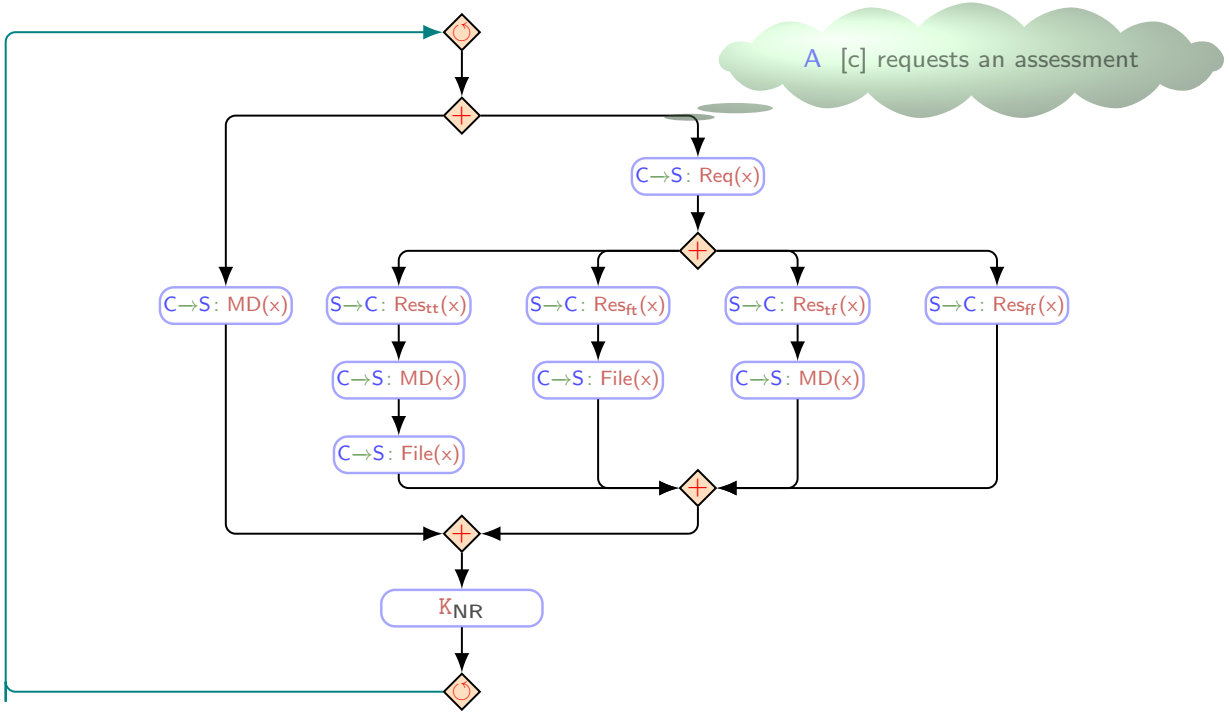

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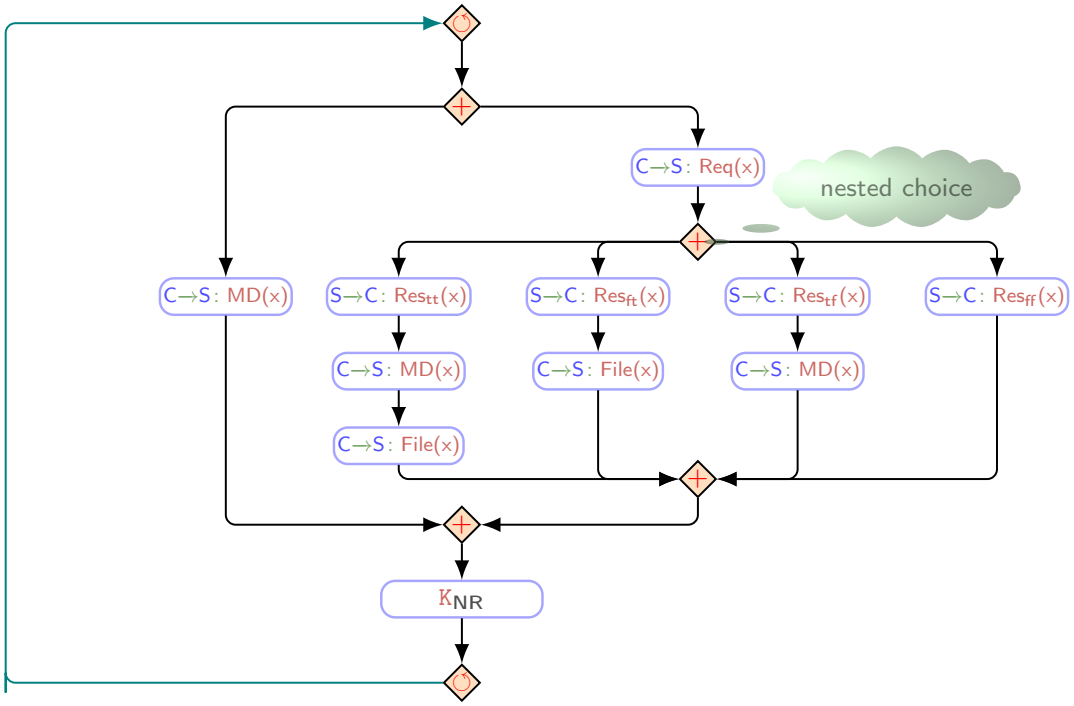

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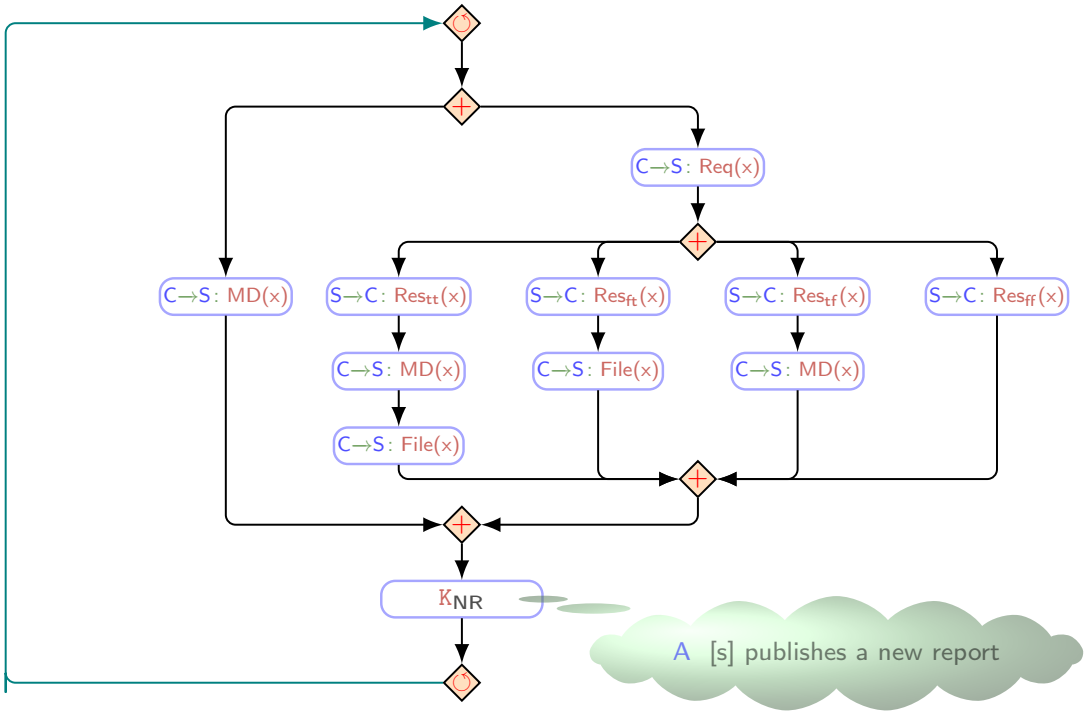
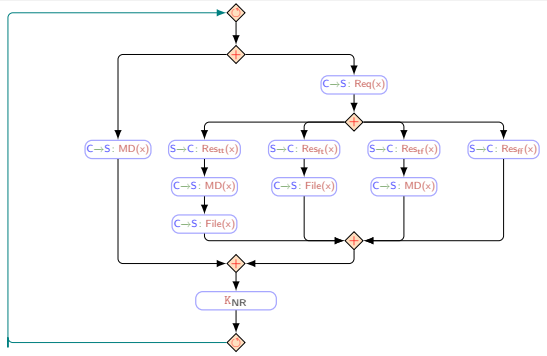


TIE...formally



$$\mathtt{K}_{\mathsf{TIE}} \triangleq \mu_{\mathsf{C}}\, X.\mathtt{K}_{\mathsf{Body}} \prec X$$

$$\mathtt{K}_{\mathsf{Body}} \triangleq (\mathtt{K}_{\mathsf{MD}}(\mathtt{x},\ell) + \mathtt{K}_{\mathsf{REQ}}(\mathtt{x},\ell)) \prec \mathtt{K}_{\mathsf{NR}}(\mathtt{x})$$

$$\mathtt{K}_{\mathsf{MD}}(\mathtt{x},\ell) \triangleq \mathsf{C} \to \mathsf{S} : (\mathtt{MD} \cdot \nu \mathtt{x} : \mathtt{Dgt} \cdot \nu \ell : \mathtt{loc})\,@\,\mathtt{b}$$

$$\mathtt{K}_{\mathsf{req}}(\mathtt{x},\ell) \triangleq \mathsf{C} \to \mathsf{S} : (\mathtt{Req} \cdot \nu \mathtt{x} : \mathtt{Dgt} \cdot \nu \ell : \mathtt{loc})\,@\,\mathtt{b}\,.\,\mathtt{K}_{\mathsf{info}}(\mathtt{x},\ell)$$

$$\begin{aligned}\mathtt{K}_{\mathsf{info}}(\mathtt{x},\ell) \triangleq\ & \mathsf{S} \to \mathsf{C} : (\mathtt{Res}_{\mathtt{tt}} \cdot \mathtt{x} : \mathtt{Dgt})\,@\,\ell\,.\,\mathtt{K}_{\mathtt{tt}}(\mathtt{x},\ell) \\ +\ & \mathsf{S} \to \mathsf{C} : (\mathtt{Res}_{\mathtt{tf}} \cdot \mathtt{x} : \mathtt{Dgt})\,@\,\ell\,.\,\mathtt{K}_{\mathtt{tf}}(\mathtt{x},\ell) \\ +\ & \mathsf{S} \to \mathsf{C} : (\mathtt{Res}_{\mathtt{ft}} \cdot \mathtt{x} : \mathtt{Dgt})\,@\,\ell\,.\,\mathtt{K}_{\mathtt{ft}}(\mathtt{x},\ell) \\ +\ & \mathsf{S} \to \mathsf{C} : (\mathtt{Res}_{\mathtt{ff}} \cdot \mathtt{x} : \mathtt{Dgt})\,@\,\ell\end{aligned}$$

Control vs Data

Behavioural types

Suitable devices for specification and analysis

- focus on control (mostly)
- assume point-to-point channels

Control vs Data

Behavioural types

Suitable devices for specification and analysis

- focus on control (mostly)
- assume point-to-point channels

VS

Klaimographies

Behavioural types with

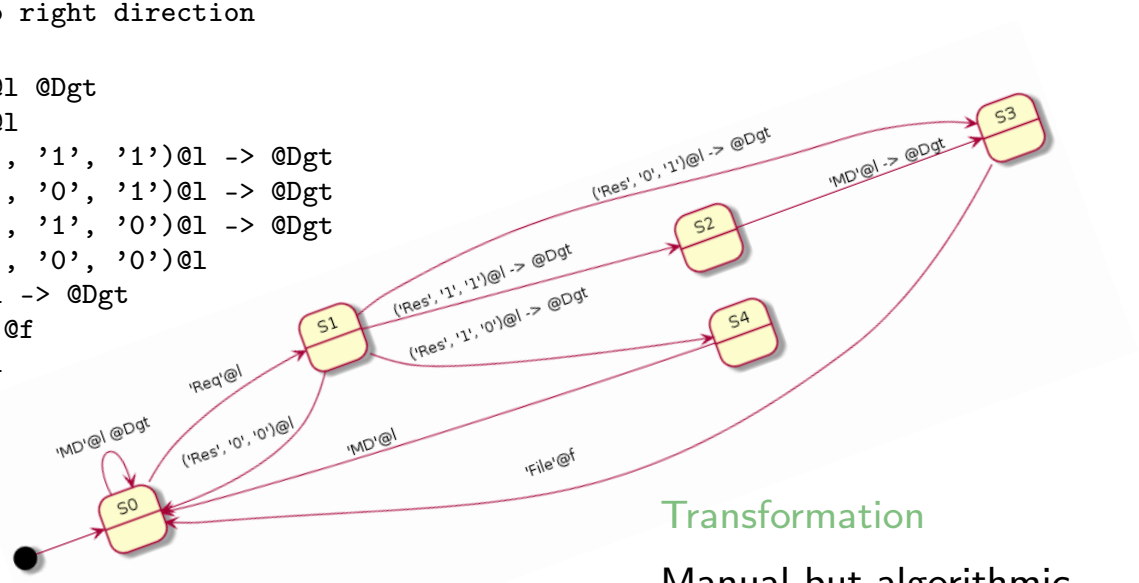
- focus on data (mostly)
- interactions based on generative communication
- unit & multi-roles

Monitors from projections

UML-like

```
@startuml left to right direction
[*] -> S0
S0 -> S0:  ’MD’ @l @Dgt
S0 -> S1:  ’Req’@l
S1 -> S2:  (’Res’, ’1’, ’1’)@l -> @Dgt
S1 -> S3:  (’Res’, ’0’, ’1’)@l -> @Dgt
S1 -> S4:  (’Res’, ’1’, ’0’)@l -> @Dgt
S1 -> S0:  (’Res’, ’0’, ’0’)@l
S2 -> S3:  ’MD’@l -> @Dgt
S3 -> S0:  ’File’@f
S4 -> S0:  ’MD’@l

@enduml
```



Transformation

Manual but algorithmic

- '@...' for data-flow analysis
- huge logs (can't fit memory)

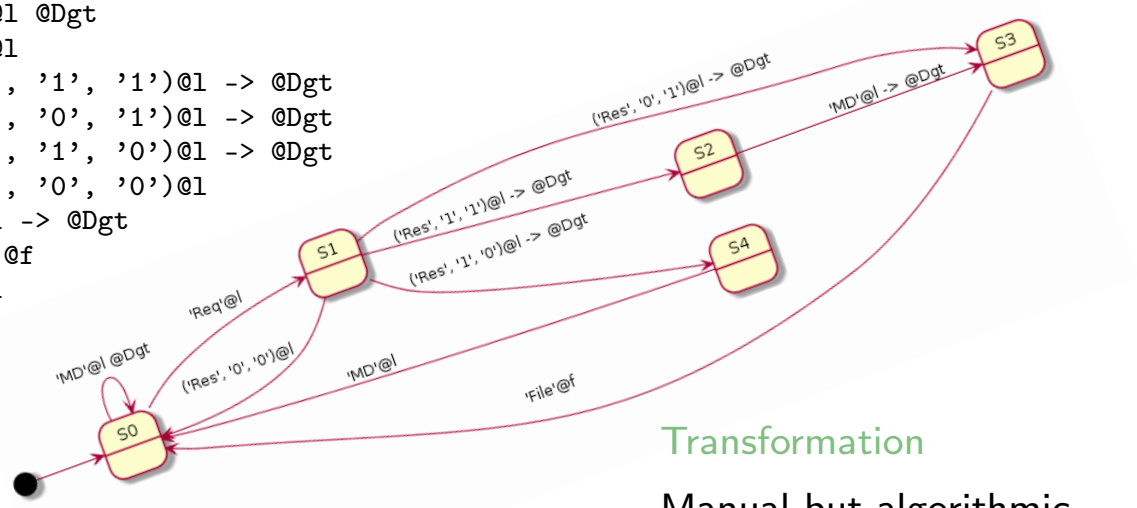
Monitor checks expected data correspondences (e.g., 'file' corresponds to a 'file req')

Monitors from projections

UML-like

```
@startuml left to right direction
[*] -> S0
S0 -> S0:  'MD' @l @Dgt
S0 -> S1:  'Req'@l
S1 -> S2:  ('Res', '1', '1')@l -> @Dgt
S1 -> S3:  ('Res', '0', '1')@l -> @Dgt
S1 -> S4:  ('Res', '1', '0')@l -> @Dgt
S1 -> S0:  ('Res', '0', '0')@l
S2 -> S3:  'MD'@l -> @Dgt
S3 -> S0:  'File'@f
S4 -> S0:  'MD'@l

@enduml
```



Violations found:
- file sent without prior reqs
- further info reqs, not honoured

Transformation

Manual but algorithmic

- '@...' for data-flow analysis
- huge logs (can't fit memory)

Monitor checks expected data correspondences (e.g., 'file' corresponds to a 'file req')

Thou shalt be abstractly precise

Effectiveness & Reproducibility

(meta-)communication with practitioners has to be smooth and amenable to be "re-played"

- non-deterministic & visual abstractions & handwaving even
  - facilitate communication
  - provide insights & "inspirations"
- but semantics is necessary
  - to attain precision
  - to change mind

Thou shalt strive for generality

How tight to TIE are we?

- klaimographies were not designed for OpenDXL
- a reviewer noted: “event-based middleware are becoming the norm”
- choreography can go bottom-up (as noted by another reviewer)

Thou shalt use appropriate tools

Other FM?

Sure, but ...

- Model checking
  but it is not easy for lay-users to express properties in some temporal logic
- Other behavioural types
  often too irksome for non-experts
- Other FM (Petri nets, event structures,...)
  too low level (and (sadly) not much studied anymore)

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