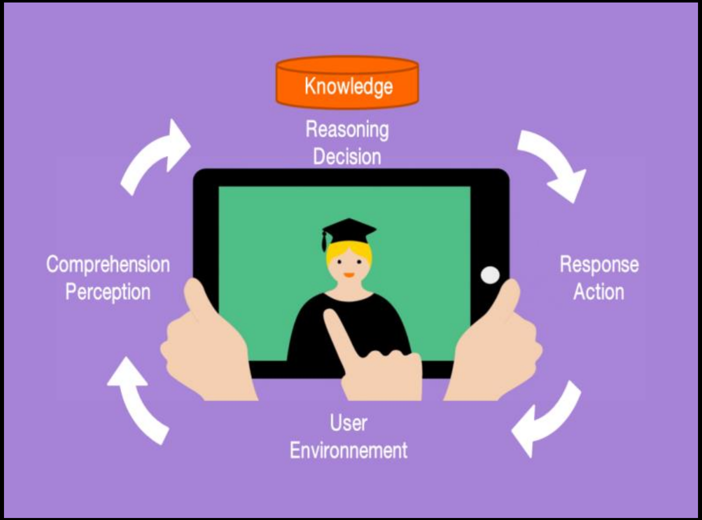
Stakes and overview of research in Artificial Intelligence and Operations Research at Orange

Henri Sanson
IMT/OLR

November 2017



Research at Orange

9 research areas

There are 9 research areas which focus on:

- supporting the Essentials2020 strategy and beyond;
- piloting our research investments.

key figures

Close to **700 research employees** (engineers, technicians, designers, sociologists, developers and marketers), including 140 PhD students.

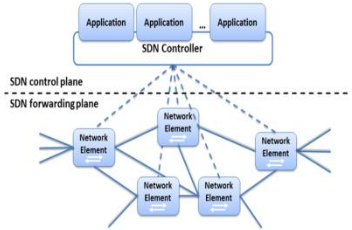
Contribution to over **80 collaborative projects** (France and Europe).

150 research partnerships with public universities and laboratories in France and worldwide.

60 research partnerships with manufacturers.

Stakes for Orange

Enlighten group entities contribute to group strategy



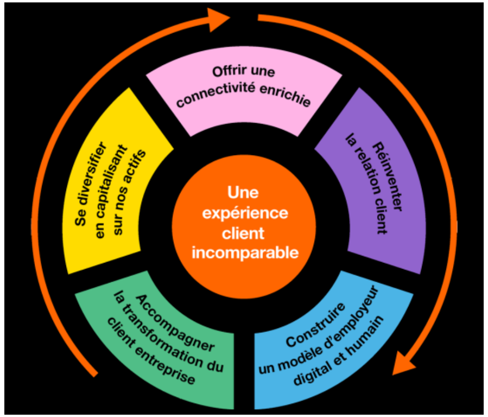
Revenue optimisation
Strategic decision making

B2B & B2C Service Innovation

Infrastructures performance & security

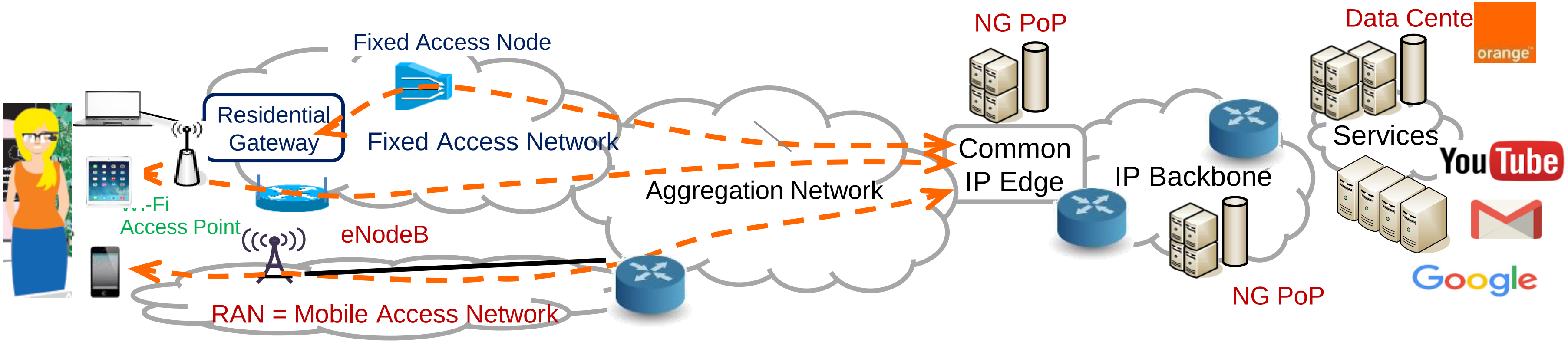
Customer relationship improvement

15 G€ investment in netwoks 2015-2018
20 M customers connectable to FTTH by 2022



Part 1: Network optimization & management problems

Monitoring & diagnosis Network functions configuration	
Data Science Reinforcement learning - Game theory	
Network design and planning	Resource allocation & placement Routing
Operations research Stochastic geometry	Operations research Stochastic geometry

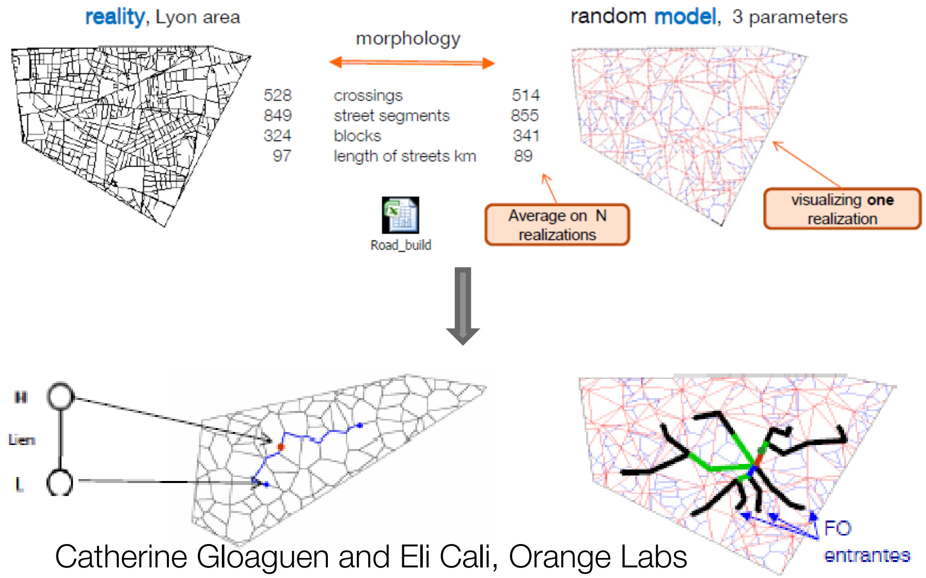


FTTH networks design optimisation: process overview

1) NRO placement optimisation

2) Decide among several architecture & deployement scenarios depending on geographic features

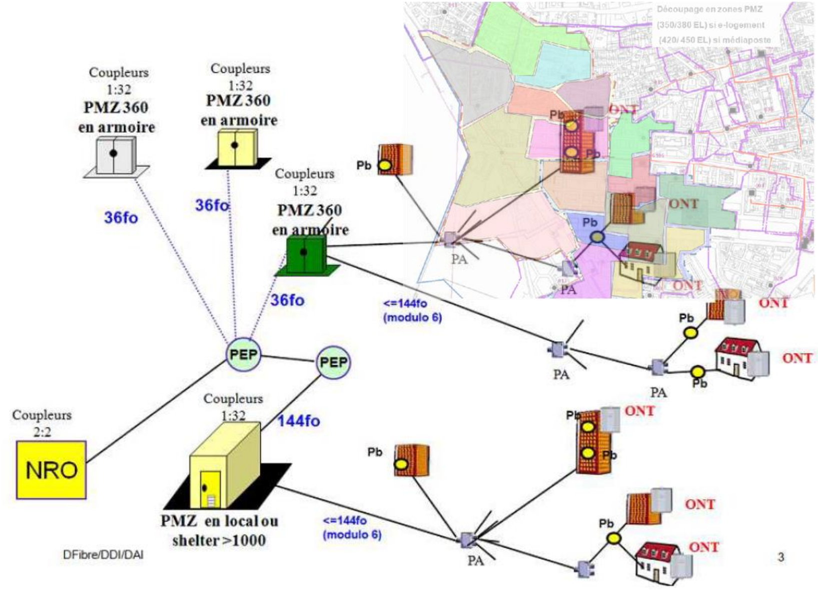
-> Network Topology Synthesis tool based on Stochastic Geometry - principle



Catherine Gloaguen and Eli Cali, Orange Labs

3) Customers partitioning + Splitters placement

4) Tree structure selection + cabling optimisation

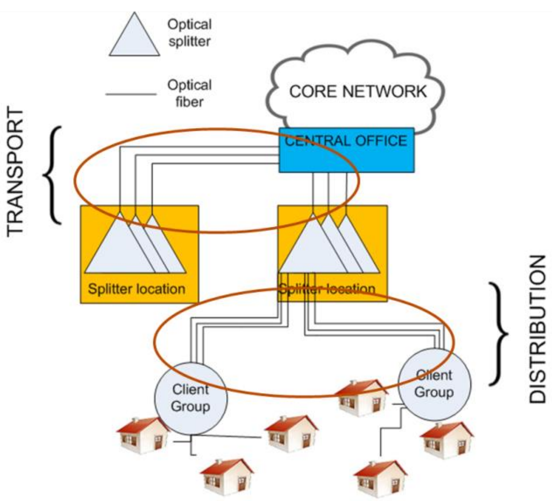


Matthieu Chardy et Al., Orange Labs

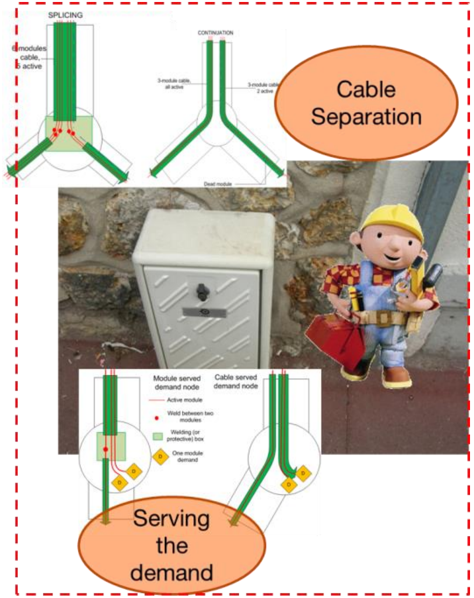
FTTH cabling optimization

Problem localization

ZMD Architecture



Features to be decided



Main lines of the solution Integer linear programming

$$
\begin{aligned}
\min \quad & \textstyle\sum_{p\in\mathcal{P}}\sum_{(i,j)\in p}\sum_{l\in\mathcal{L}} c_l \cdot d_{i,j} \cdot (K_{p,l}^{born,sep} + K_{p,l}^{born,dem} + K_{p,l}^{ctn,sep} + K_{p,l}^{dem,ctn}) \\
+ \quad & \textstyle\sum_{i\in V^*}\sum_{m\in\mathcal{M}_L} PW_m \cdot W_{i,m} \\
+ \quad & \textstyle\sum_{p\in\mathcal{P}}\sum_{l\in\mathcal{L}} PB_l \cdot (K_{p,l}^{born,sep} + K_{p,l}^{ctn,sep})
\end{aligned}
$$

such that

$$
\forall i \in V_N, \sum_{p\in\mathcal{P}|\omega(p)=i} (m_p^{born,sep} + m_p^{ctn,sep}) =
$$

$$
\sum_{p\in\mathcal{P}|\alpha(p)=i} (m_p^{born,sep} + m_p^{ctn,sep}) + \sum_{p\in\mathcal{P}|\alpha(p)=i,\omega(p)\in V_D} \sum_{l\in\mathcal{L}} D_{\omega(p)}^{mod} \cdot (K_{p,l}^{born,dem} + K_{p,l}^{ctn,dem})
$$

$$
\forall i \in V_D, \sum_{p\in\mathcal{P}|\omega(p)=i} (m_p^{born,sep} + m_p^{ctn,sep}) + \sum_{p\in\mathcal{P}|\omega(p)=i} \sum_{l\in\mathcal{L}} D_i^{mod} \cdot (K_{p,l}^{born,dem} + K_{p,l}^{ctn,dem}) =
$$

$$
D_i^{mod} + \sum_{p\in\mathcal{P}|\alpha(p)=i} (m_p^{born,sep} + m_p^{ctn,sep}) + \sum_{p\in\mathcal{P}|\alpha(p)=i,\omega(p)\in V_D} \sum_{l\in\mathcal{L}} D_{\omega(p)}^{mod} \cdot (K_{p,l}^{born,dem} + K_{p,l}^{ctn,dem})
$$

$$
\forall p \in \mathcal{P}, \sum_{l\in\mathcal{L}} M_l \cdot K_{p,l}^{born,sep} \geq m_p^{born,sep}
$$

$$
\forall p \in \mathcal{P}, \sum_{l\in\mathcal{L}} (M_l - 1) \cdot K_{p,l}^{ctn,sep} \geq m_p^{ctn,sep}
$$

$$
\forall i \in V^*, \forall l \in \mathcal{L}, \sum_{p\in\mathcal{P}|\alpha(p)=i} K_{p,l}^{ctn,sep} + K_{p,l}^{ctn,dem} \leq \sum_{p\in\mathcal{P}|\omega(p)=i} K_{p,l}^{born,sep} + K_{p,l}^{ctn,sep}
$$

$$
\forall i \in V^*, \sum_{p\in\mathcal{P}|\omega(p)=i} \sum_{l\in\mathcal{L}} K_{p,l}^{born,sep} + K_{p,l}^{ctn,sep} \leq 1
$$

$$
\forall i \in V_D, \sum_{l\in\mathcal{L}} \sum_{p\in\mathcal{P}|\omega(p)=i} K_{p,l}^{born,dem} + K_{p,l}^{ctn,dem} \leq 1
$$

$$
\forall i \in V^*, \sum_{m\in\mathcal{M}_L} m \cdot W_{i,m} = \sum_{p\in\mathcal{P}|i=\alpha(p)} m_p^{born,sep} + \sum_{p\in\mathcal{P}|\alpha(p)=i,\omega(p)\in V_D} \sum_{l\in\mathcal{L}} D_{\omega(p)}^{mod} \cdot K_{p,l}^{born,dem}
$$

$$
\forall i \in V^*, \sum_{m\in\mathcal{M}_L} W_{i,m} \leq 1
$$

Vincent Angelilla and Matthieu Chardy, Orange Labs

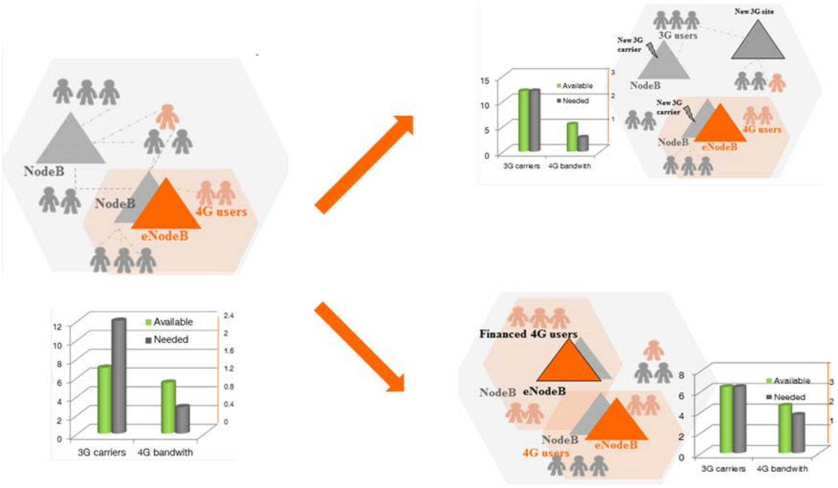
Evaluated impact: 10% saving of cabling cost

3G/4G load-balancing optimization for mobile network planning

Problem statement

Optimize progressive migration from 3G to 4G in order to best meet te demand in traffic and connectivity while respecting budget constraints:

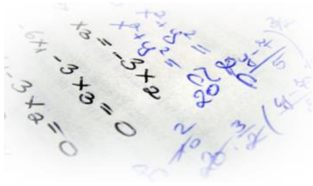
- Allocate new radio resources
- Intensification of 3G and 4G sites (increased capacity)
- 4G network expansion (more cells)
- number of 4G subscriber's packages to subsidize

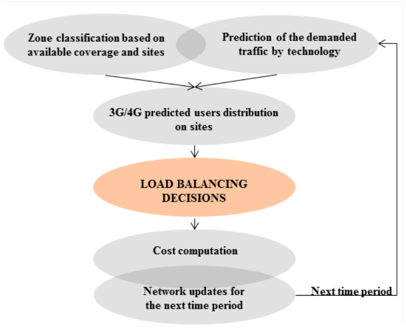


Main lines of the solution

Integer linear programming for mono-périod problem

integrated in a sequential resolution schema for multi-periods



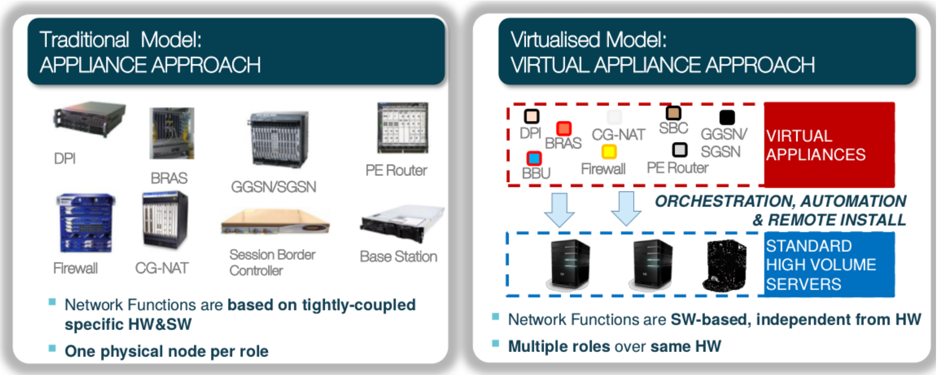


Mariem Ben Yahia, Yu Bao, Matthieu Chardy, Orange Labs

Virtualization : a major new step in telecom networks transformation

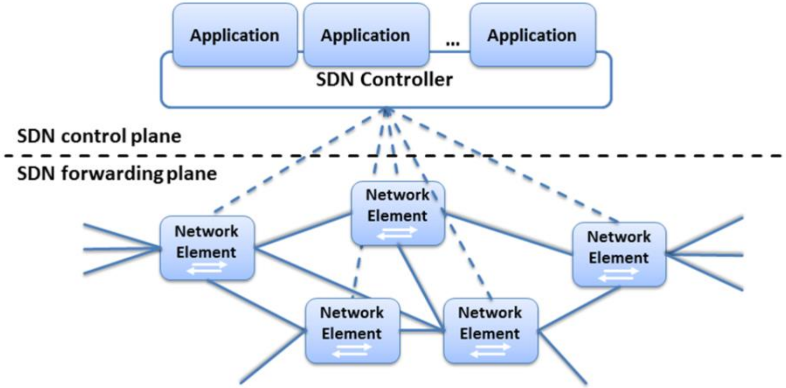
NFV = Network Function Virtualization

Decoupling of hardware and software
Generic and affordable hardware
Multiple Network functions can be deployed on the same hardware



SDN : Software Defined Network

Programmable network
-> Flexible configuration



Virtualized networks overview

Overall virtualized network management architectural framework

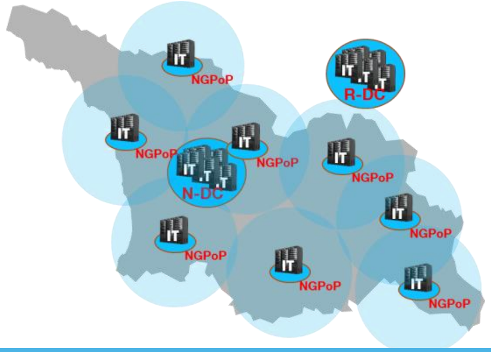
NFV Orchestrator
VNF instanciation & chaining
end-to-end network service management

Management Plane -> VNF Manager
VNF (incl. SDN controler) setting

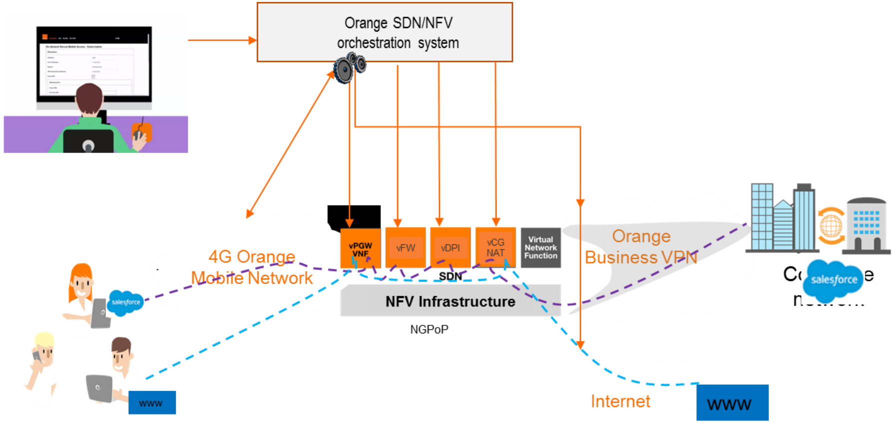
Control Plane -> SDN controler
Routing & packet processing policy

Data Plane -> switch
Packet swithing / forwarding

Geographical view

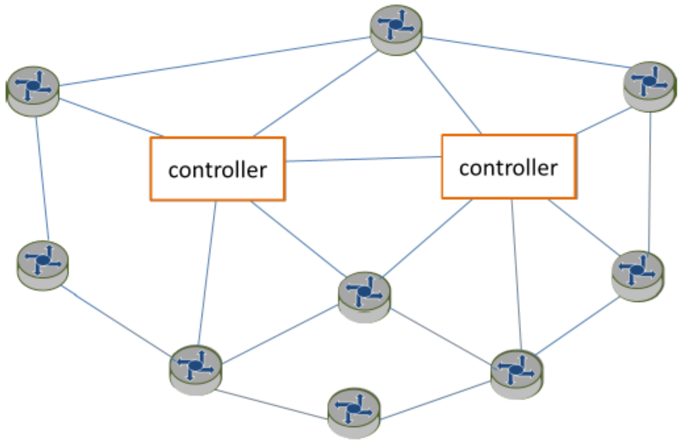


Example use case



Optimal Controler placement

Problem statement



Objectives:
- Minimize the number of controllers:
- Optimal placement of controllers
- Node assignment to controllers

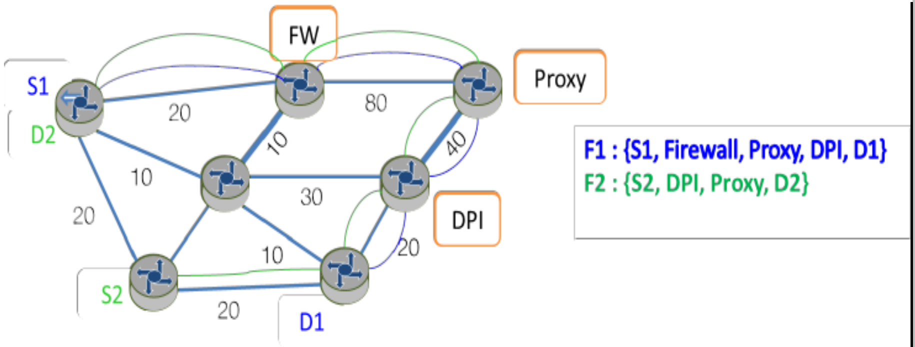
Constraints:
- each router j must be covered by at least one controller within the latency bound lmax ,
- each router j must be assigned to the nearest active controller,
- all pairs of controllers must respect the allowed inter-controllers latency lcc ,
- the difference of load between all pairs of controllers must be at most δ (load balancing constraints).

=> Main lines of the solution: Integer linear programming problem

Nancy Perrot, Orange Labs

Service (Virtual) function chaining

Problem statement



Given:
- a network with capacities on nodes (for functions) and on arcs (for traffic flows),
- a set of traffic services with ordered functions

Find: the optimal placement of functions in the network nodes jointly to the traffic routing s. t.
- each flow is processed by the functions in the right order while respecting the network capacities (nodes and arcs),
- affinity and anti-affinity rules,
- the end-to-end latency.

Main lines of the solution

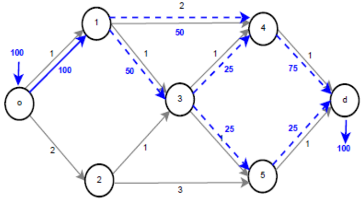
Relaxed problem : optimal allocation of VNF on pre-computed routes.
1. Compute LP optimal solution.
2. Rounding sub-routine : selection of an admissible path (deterministic or random walk over the fractional paths).
3. VNF opt : Use the VNF deployment model to optimally deploy VNFs on the selected routes. Update the network capacities.
4. Allocate remaining service chains : unfeasible service chains are allocated in serial with the ILP.

On going work

Nancy Perrot & Alham Mouacy, Orange Labs

Optimized routing strategies for Orange IP Global Network

Problem statement



$$Load(i,j) = \frac{\sum_{k \in K} Flow^k(i,j)}{capacity(i,j)}$$

Reference routing (IGP):

- Compute the shortest paths for all (O,D) pairs
- Split Flow(O,D) at each router according to shortest paths
- Resulting link load

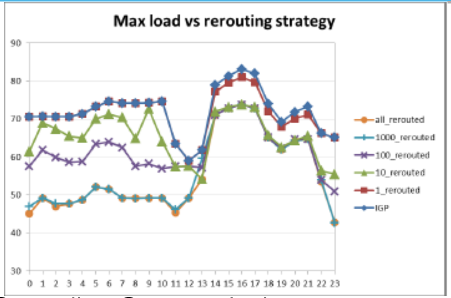
Propose alternative (optimized) approaches to **minimize the network congestion** AND **reduce the load of most loaded links**

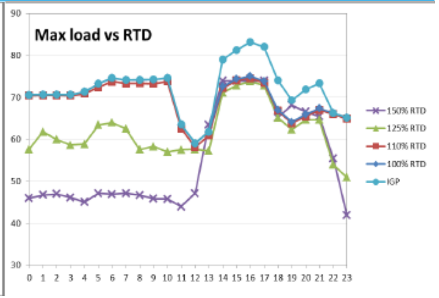
Main lines of the solution

a UNIQUE routing for each O-D pair, over all the time slots
not to deteriorate (too much) the IGP delay
network congestion = load of the most loaded link

1) Perform reference (IGP) routing -> link load stats
2) Select a subset of O-D pairs to be rerouted
3) Solve successively the Maximum Concurrent Flow problem by focusing on the most remaining loaded links at each step.

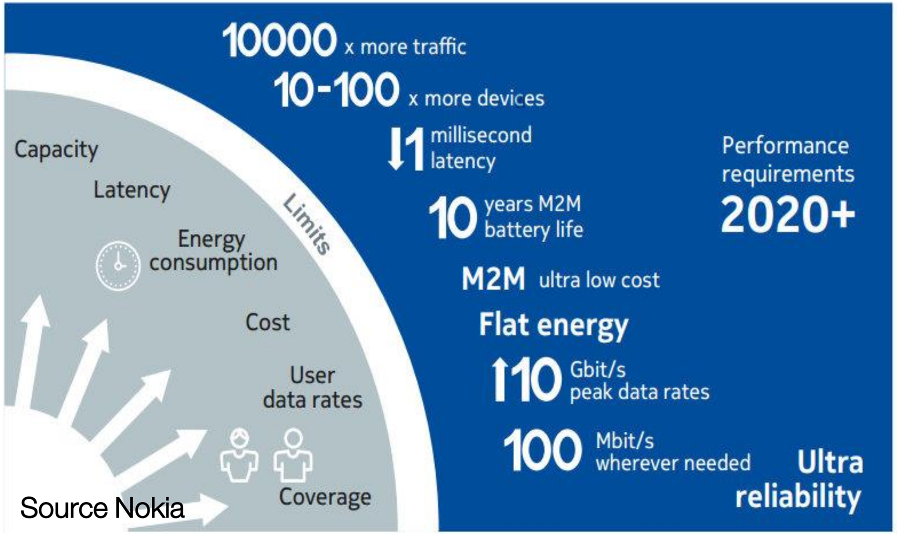
Result





Amal Benhamiche & Eric Gourdin, Orange Labs

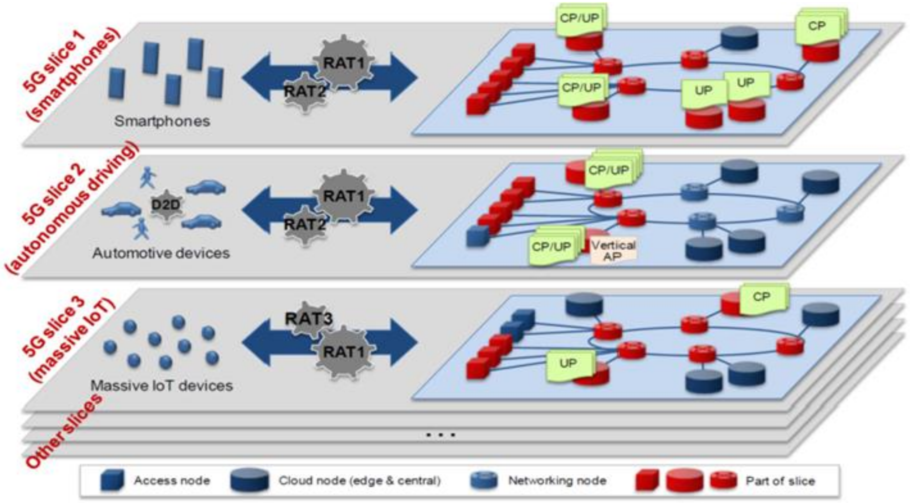
5G: the future unified telecom infrastructure for a genuine ambiant connectivity



Source Nokia

Several radio interfaces
Fixed – mobile convergence,
Globally virtualized, from day 1, Network-Cloud convergence
Device-to-Devices communication functionalities

Slices for vertical usages : smart cities, transport, health, TV, ..



Some research problems addressed for 5G networks

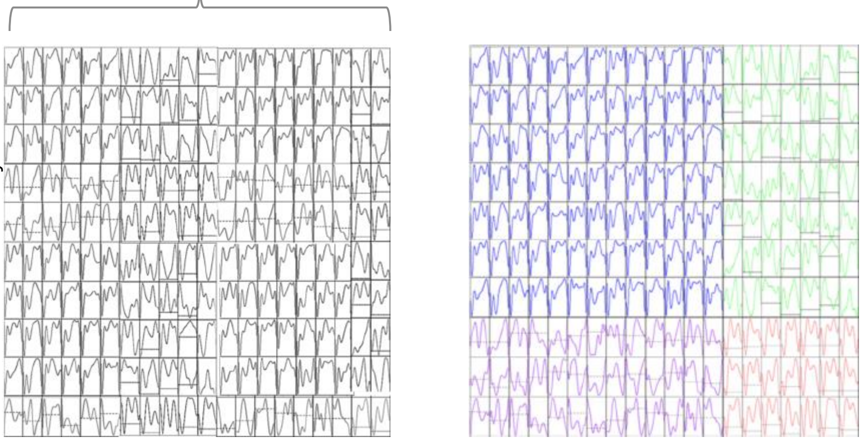
- Slices-related optimization problems:
  - Service Function Chaining Problem and Multi-layer Network Design (to design a slice = a virtual network),
  - Virtual Network Embedding (to embed several slices/VN in the physical infrastructure),
- D2D-related modeling & optimization problems:
  - Global connectivity feasibility (stochastic geometric – continuous percolation theory)
  - Radio resource allocation and demand routing (OR – optimisation)
- Spectrum management
  - Leveraging unlicenced spectrum or licensed spectrul allocated to non-telco services in complement to primary licensed spectrum for offloading part of the traffic -> Licenced Assisted Access & Licenced Shared Access mechanisms
  - Offloading strategy and/or price negociation strategy analysis based on games theory.

Applications to RAN monitoring & diagnosis

Discover different characteristic working patterns

p (170) RAN KPIs, all day long
(accessibility, retainability, integrity)

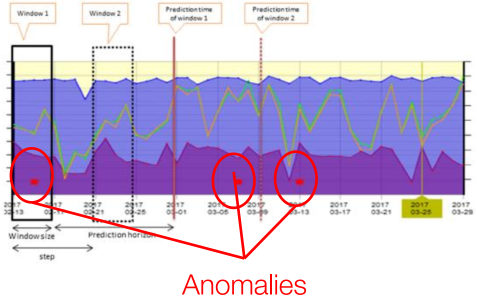
C cells x D days

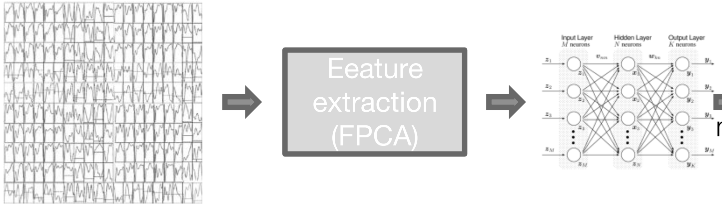


Principle: SEM after functional PCA
Applications: simplified monitoring for troubleshooting, RAN planning,,

Predict (forecast) anomalies

Predict future anomalies of different types:
accessibility, retainability, integrity
Through superised learning

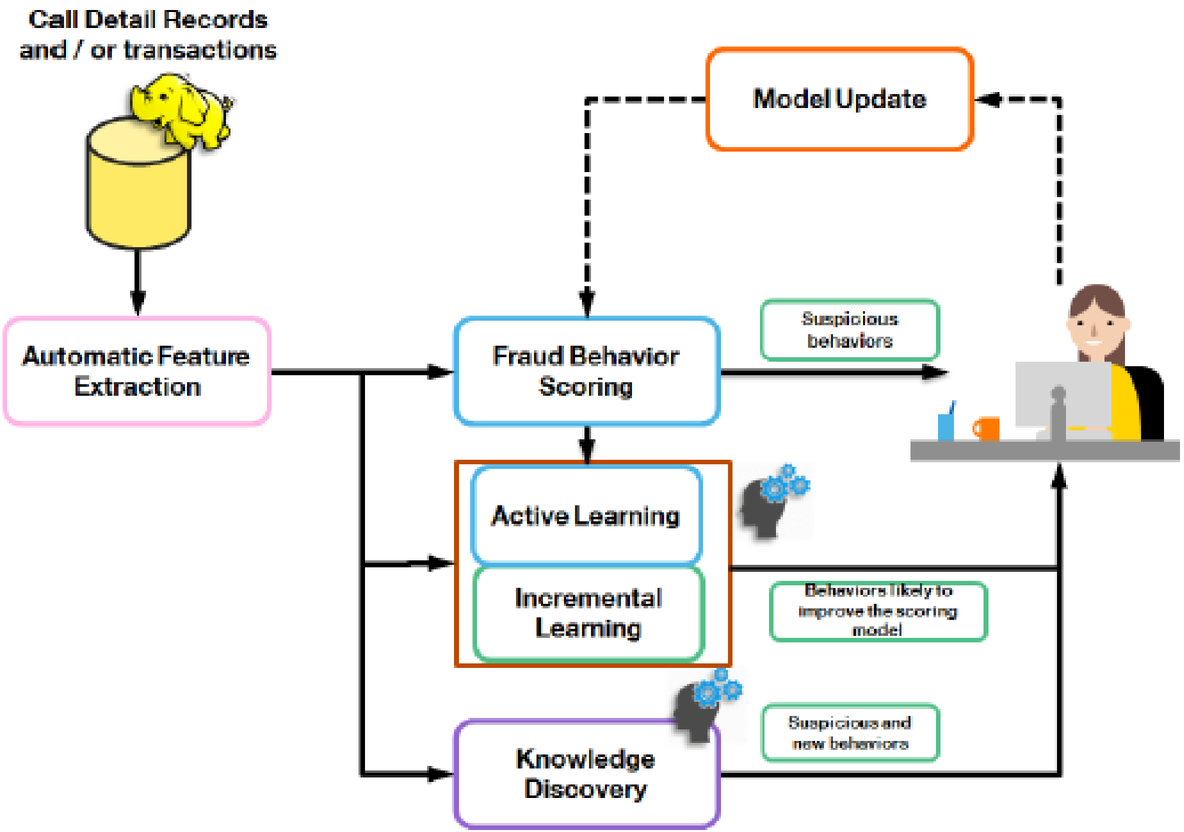




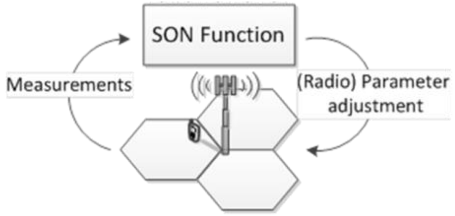
Cell status:
normal / abnormal

(from Yosra Ben Slimen & Sylvain Allio, OLN/GDM)

Toward a global approach to fraud detection



Applications to RAN SON functions setting

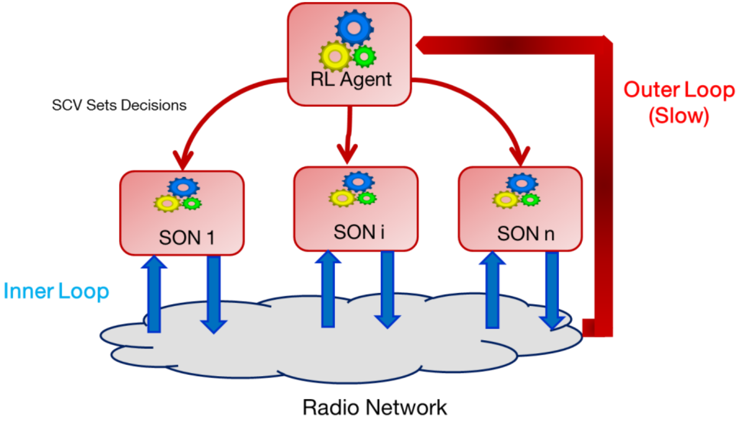


A SON function is a control loop that adjusts the network parameters based on the measurements feedback

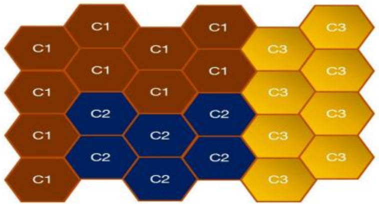
SON functionalities are thesmselves becoming **very diverse, targeting several aspects and parameters** of the network

Their **individual objectives may be conflicting** as well -> need orchestration

Reinforcement learning
(UCB bandit algorithm)



Combinatorial issue:
SON functions x # configurations x # cells
Solution: group cells with similar characeristics

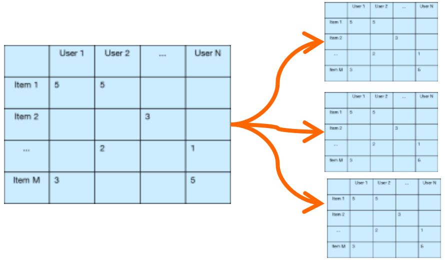


(Sana Ben Jemaa & Tony Daher, Orange Labs)

Part 2: General Data Science tools

Toward increased Data Mining automation with a generic toolbox ?

Automatic feature extraction aiming at parcimony

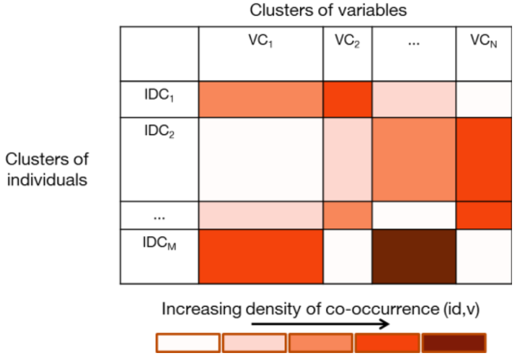


Variable construction from multi-tables

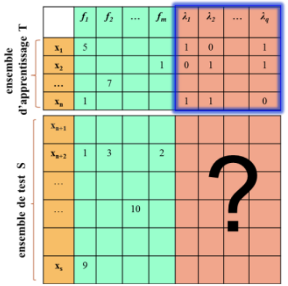
Univariate discretization

Bayesian + information theory framework

Co-clustering

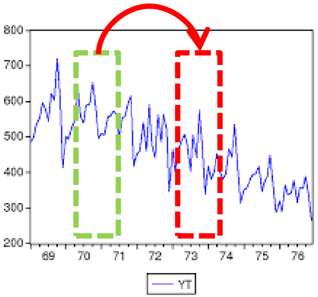


Interactive multi-labels tagging

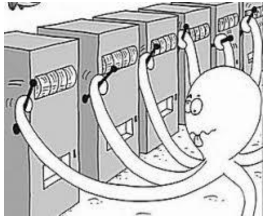


Time series analysis

forecasting

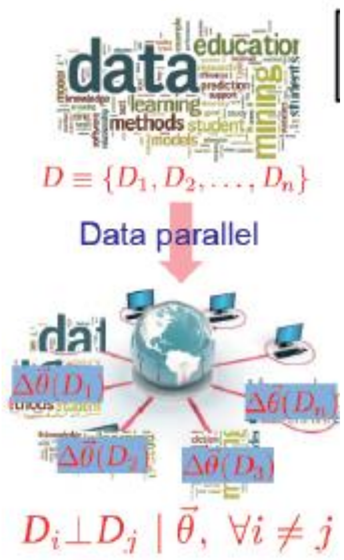


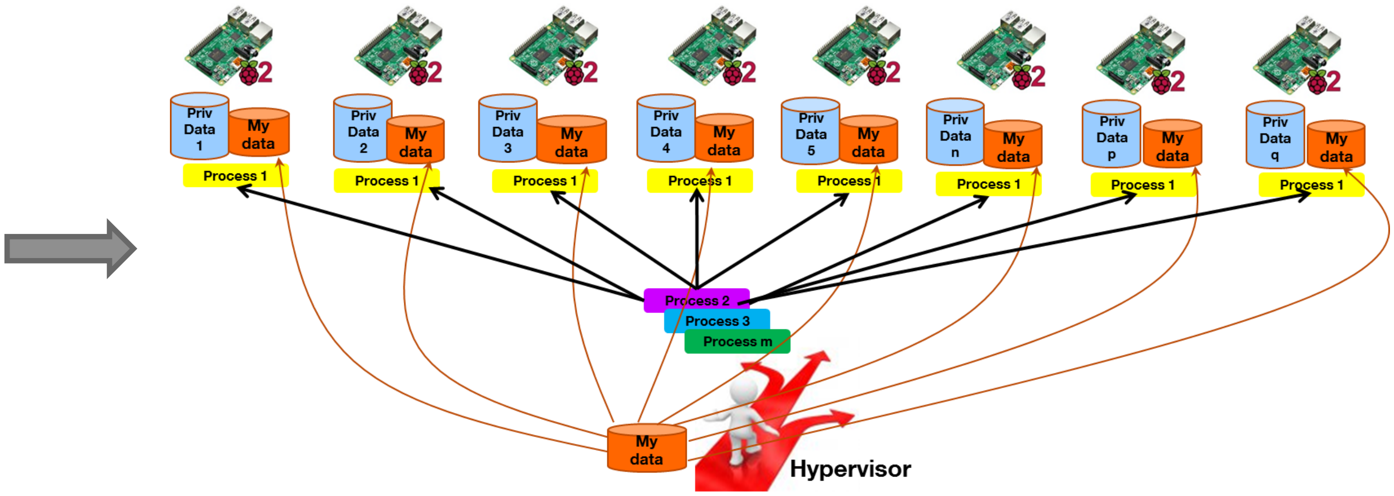
Reinforcement learning (bandits)



Federated (ubiquitous) learning for knowledge extraction in siloted data sets

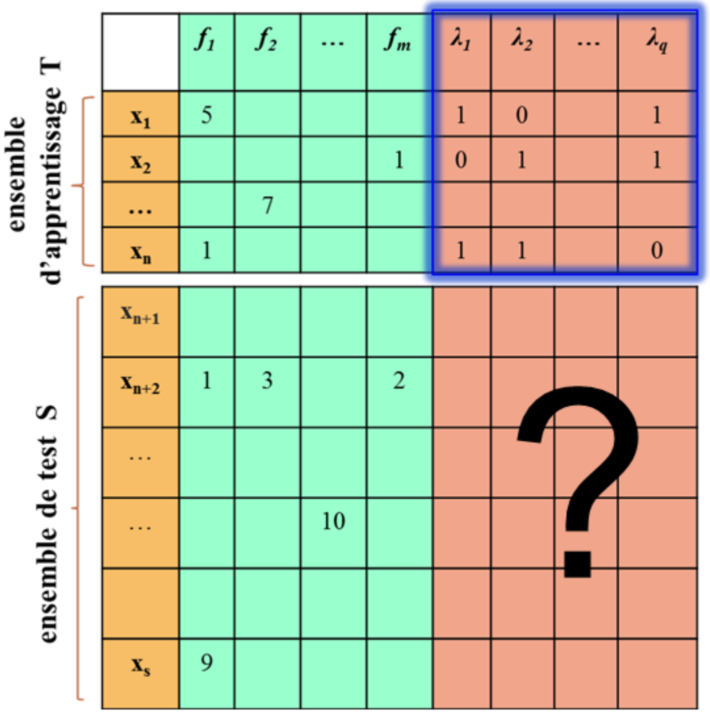
$$\vec{\theta}^{t+1} = \vec{\theta}^{t} + \Delta_f \vec{\theta}(D)$$



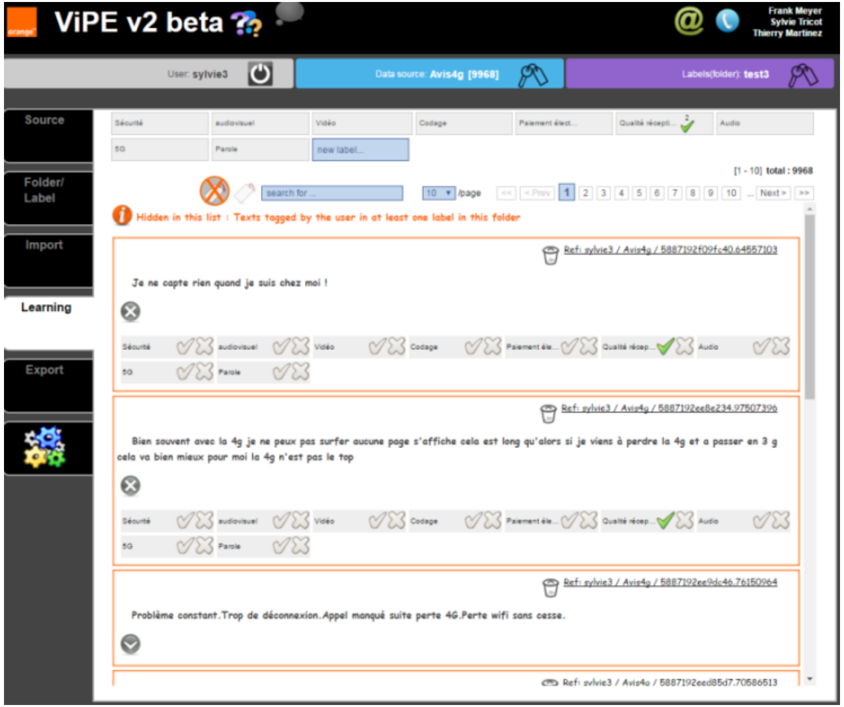


Text Mining: interactive labeling of short texts

iInteractive multi-labels classification (scoring)



http://egc2017.imag.fr/demonstrations/vipe-un-outil-interactif-de-classification-multilabel-de-messages-courts/

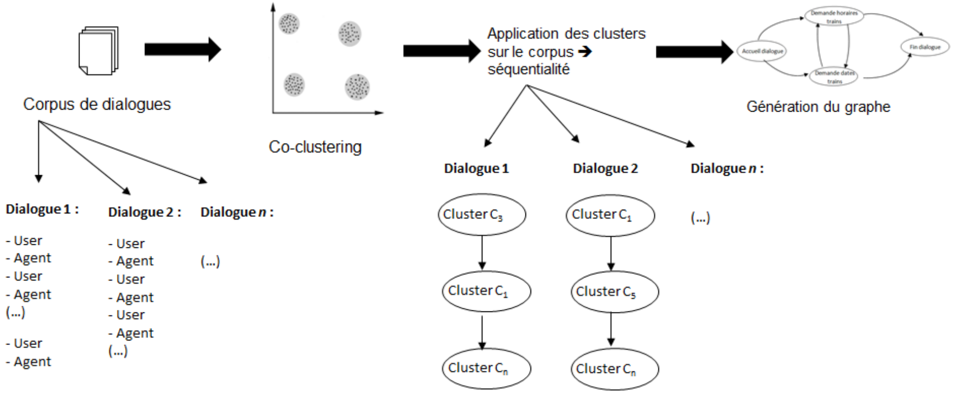


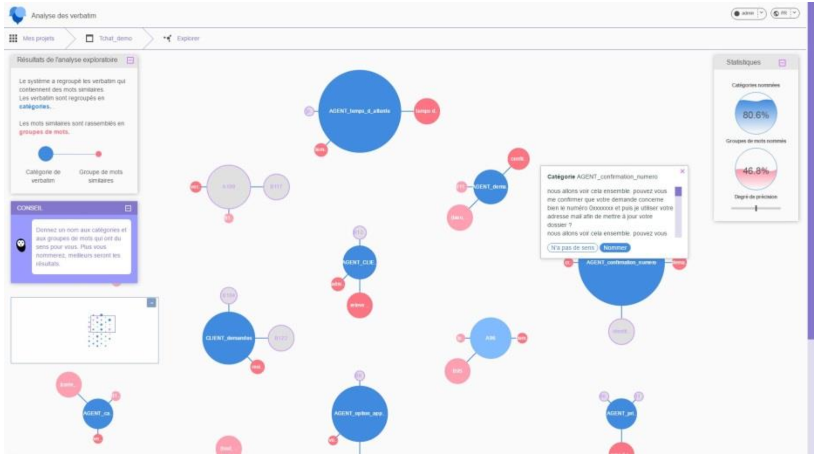
Current focus: extreme multi-label classification: ~ 1M variables & ~ 1M labels

(Frank Meyer et Wissam Siblini., Orange Labs)

Text Mining for dialog graphs (chatbots) bootstrapping

Joint clustering of dialog acts and related words in customers – agents conversations histories

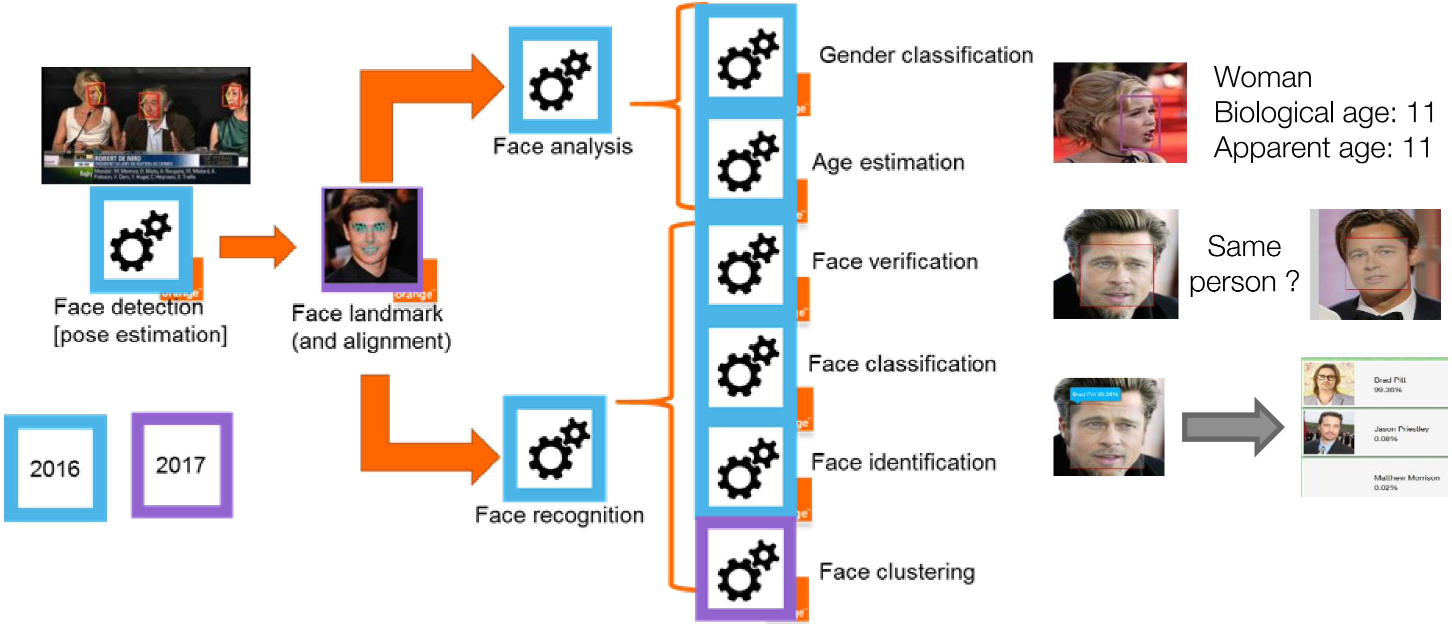




(Jean-Léon Bouraoui & Vincent Lemaire, Orange Labs)

Part 3: anthropomorhic Artificial Intelligence

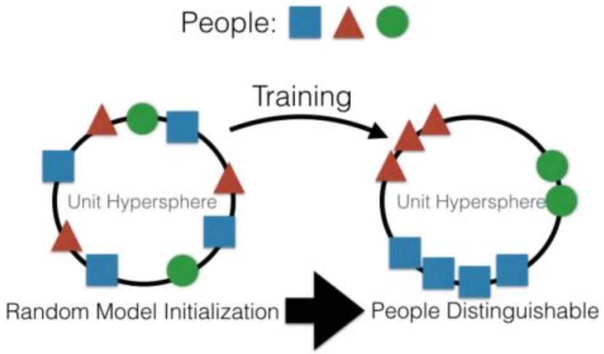
Face recognition



Some applications

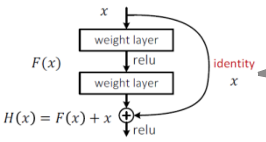
(Adria Arrufat, Grigory Antipov, Moez Baccouche, Stéphane Pateux, Orange Labs)

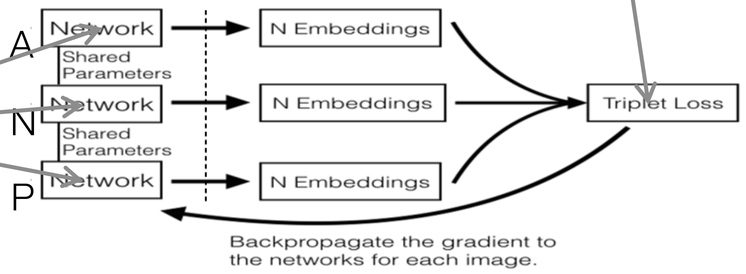
Face verification through embeddings computation



Triplet Loss: $\sum_{i}^{N} \left[\|f(x_i^a) - f(x_i^p)\|_2^2 - \|f(x_i^a) - f(x_i^n)\|_2^2 + \alpha \right]_+$

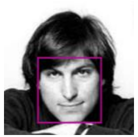
Deep ANN architecture: ResNet50





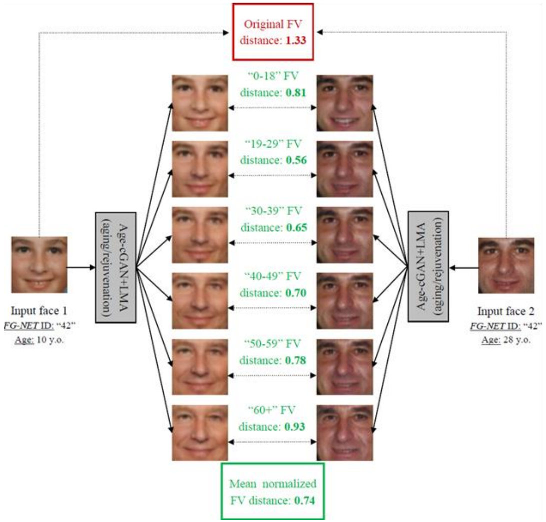
Techno	Type	Corpus / benchmark	SotA
Detection	Accuracy @ 100 faulse alarmes	FDDB	95.50%(Orange)
Recognition(vérification)	Accuracy	LFW (identity)	99.63% (Google) (Orange: 99.51)

Cross-age face verification

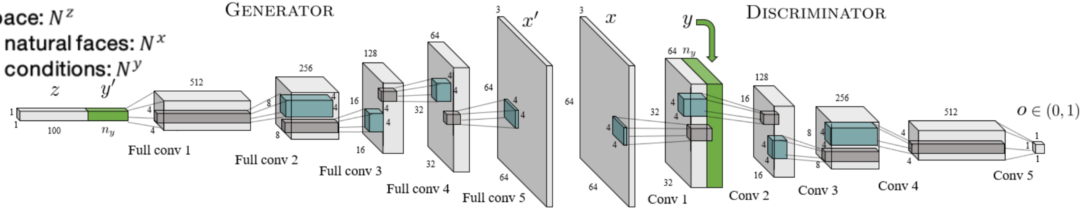


Same person ?

Age Normalization Prior to Identity Verification

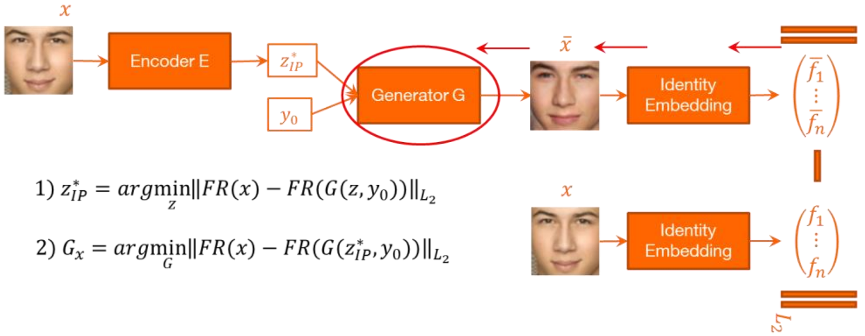


The core: compute the conditional generator G using adversarial learning (GAN)



$$\min_G \max_D V(D,G) = \mathbb{E}_{x,y\sim p_{data}}[\log D(x,y)] + \mathbb{E}_{z\sim p_z(z),\tilde{y}\sim p_y}[1-\log D(G(z,\tilde{y}),\tilde{y})]$$

Compute the encoder E inverse of generator G



1) $z^*_{IP} = \underset{z}{argmin}\|FR(x) - FR(G(z,y_0))\|_{L_2}$

2) $G_x = \underset{G}{argmin}\|FR(x) - FR(G(z^*_{IP},y_0))\|_{L_2}$

Combine all with embeddings-based face verification

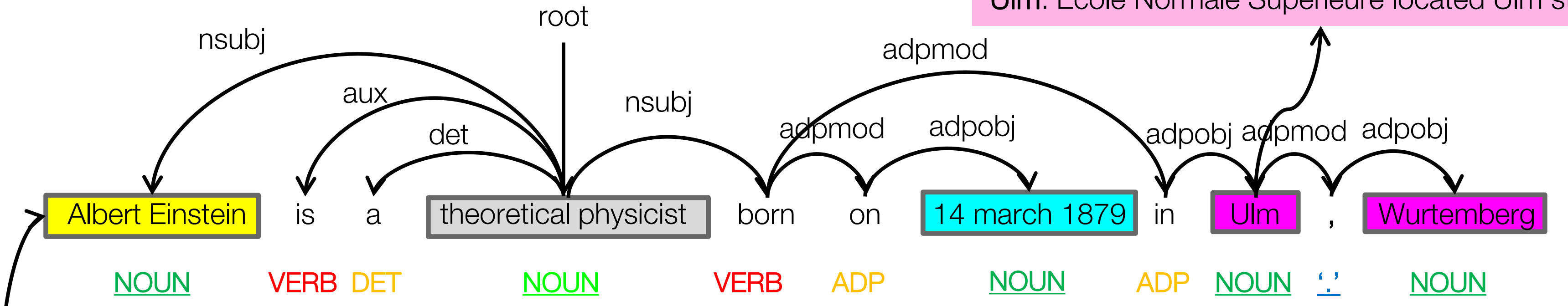
Reconstruction Approach	FV Score (Protocol 1)*	FV Score (Protocol 2)**
Only encoder E: x_0	89,0%	78,1%
Pixelwise optimization: x_{pixel}	94,5%	78,5%
Identity-preserving optimization: x_{pixel}	**97,6%** (max = 100%)	**82,0%** (max = 89,4%)

Natral language understanding: the ultimate goal

To understand an utterance = generate a représentation of its sense exploitable by the machine for further processing -> combines 3 levels of analysis

- lexical: named entities persons locations dates terms disambiguation synonymy
- sentence: part-of-speech dependencies Proposition semantics
- discurse: co-references resolution

Ulm: ville du Bade-Wurtemberg
Ulm: Ecole Normale Supérieure located Ulm street



Semantic frames

TheoreticalPhysicist (Albert Einstein)

ToBeBorn(Agent: TheoreticalPhysicist , Time: 14 march 1879, AtLoc: Ulm),

In (Ulm, AtLoc: Wurtemberg)

He publishes his special theory of Relativity in1905 and his theory of gravitation so-called of General Relativity in 1916.

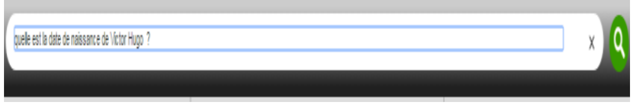
Natural language understanding and knowledge management

Formalization of human knowledge present in documents

dynamisés par sa présence. Wilson préconise l'envoie d'un corps expéditionnaire britannique en France en cas d'attaque allemande.



Semantic search in natural language



Reasoning

∀ X, Person(X) ∧ Command(X, Army Corps)
=> General(X)
Occupation(Henry Hughes Wilson, Y) ?

Toward automatic dialog generation ?

To capitalize all academic and business human knowledge present in textual and multimedia documents (« 80% of circulating information is unstructured»)

Dependency parsing: Orange Labs solution (work in progress)

Dependency labels

Label	Description	Label	Description	Label	Description
acomp	adjectival complement	compmod	compound modifier	nmod	noun modifier
adp	adposition	conj	conjunct	nsubj	nominal subject
adpcomp	complement of adposition	cop	copula	nsubjpass	passive nominal subject
adpmod	adpositional modifier	csubj	clausal subject	num	numeric modifier
adpobj	object of adposition	csubjpass	passive clausal subject	p	punctuation
advcl	adverbial clause modifier	dep	generic	parataxis	parataxis
advmod	adverbial modifier	det	determiner	partmod	participial modifier
amod	adjectival modifier	dobj	direct object	poss	possessive
appos	appositive	expl	expletive	prt	verb particle
attr	attribute	infmod	infinitival modifier	rcmod	relative clause modifier
aux	auxiliary	iobj	indirect object	rel	relative
auxpass	passive auxiliary	mark	marker	xcomp	open clausal complement
cc	conjunction	mwe	multi-word expression		
ccomp	clausal complement	neg	negation		

Transition-based parsing

Configuration: (S, B, A) $[S = \text{Stack},\ B = \text{Buffer},\ A = \text{Arcs}]$

Initial: $([\ ], [0, 1, \ldots, n], \{\ \})$

Terminal: $([0], [\ ], A)$

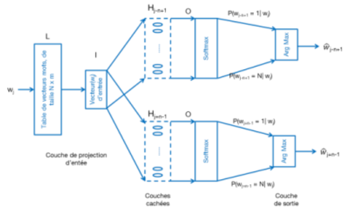
Shift: $(S, i|B, A) \Rightarrow (S|i, B, A)$

Right-Arc(k): $(S|i|j, B, A) \Rightarrow (S|i, B, A \cup \{(i, j, k)\})$

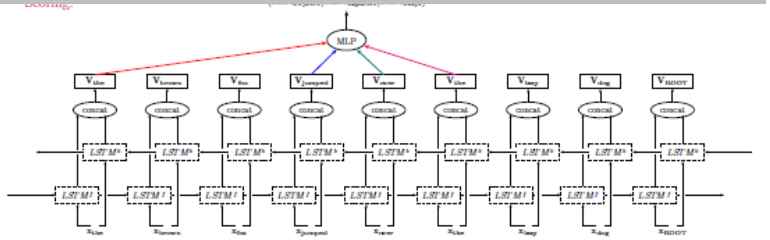
Left-Arc(k): $(S|i|j, B, A) \Rightarrow (S|j, B, A \cup \{(j, i, k)\})$ $i \neq 0$

1) POS tagging (UPOS)

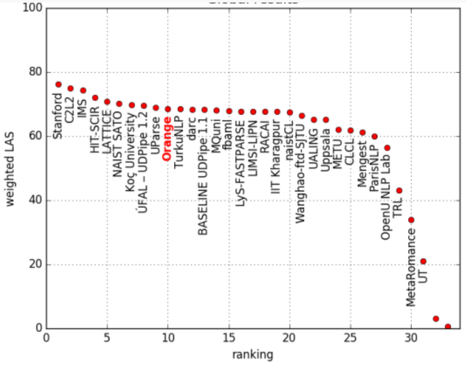
2a) pre-training word embeddings (Word2Vec)



2b) Transition-based parsing learning using B-LSTM



CoNLL
The SIGNLL Conference on Computational Natural Language Learning



(Munshi Asadullah, Johannes Heinecke, Ghislain Putois, Orange Labs)

Merci