Five Nines of Southbound Reliability in Software-Defined Networks

Francisco J. Ros

Pedro M. Ruiz

University of Murcia

The Problem

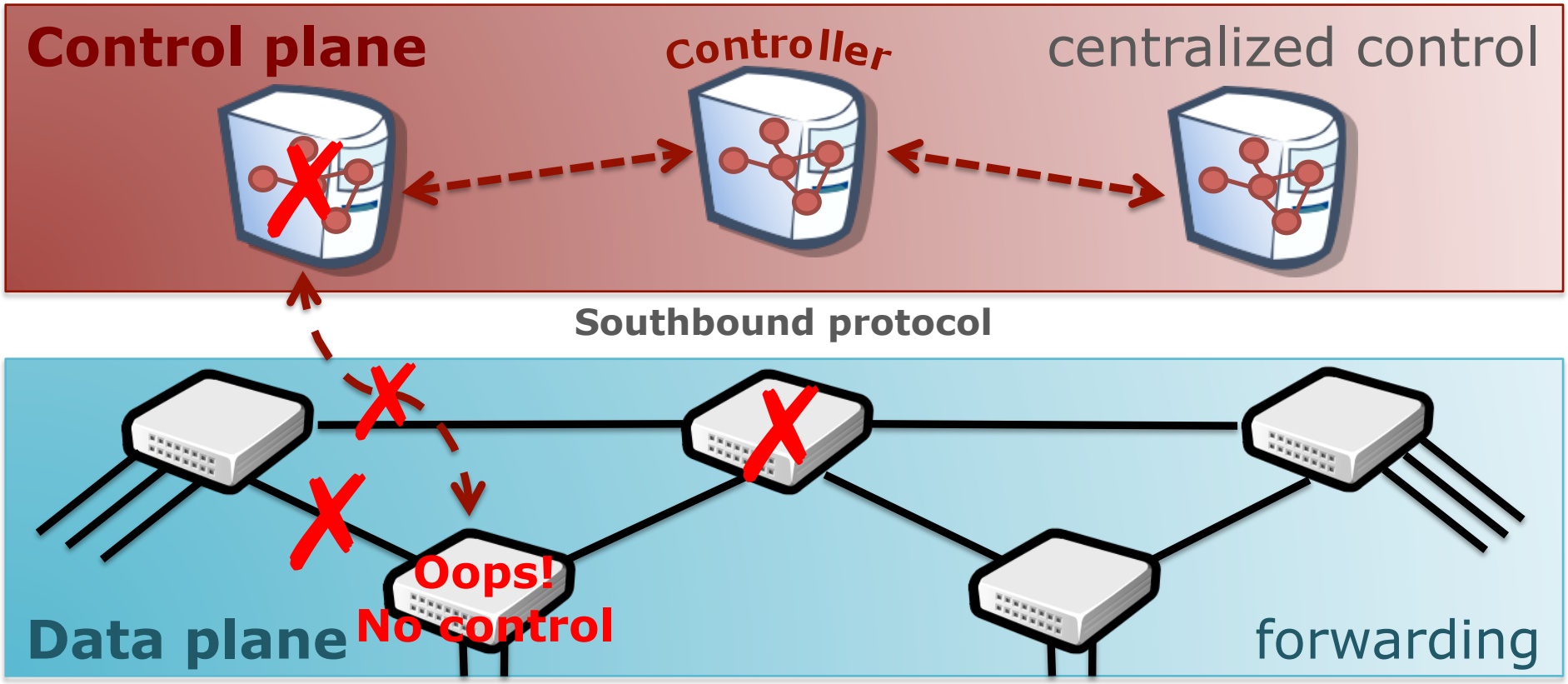
+ Enables programmability
+ Facilitates innovation

Network App

Northbound API

− Resiliency?

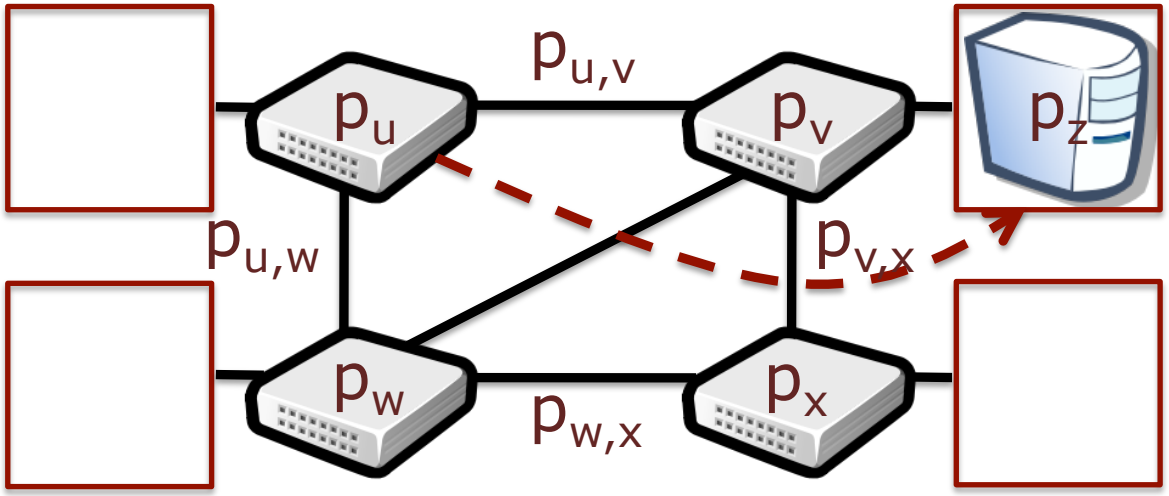
Challenge for network operators



Our Objective

- Communication between any node and (at least) one controller guaranteed with high probability
- At least **five 9's** reliability in the Southbound interface
  - **How many controllers?**
  - **Where?**
  - **What controllers per node?**

How guarantee that u,v,w,x can connect to z with P>0.99999?



p ≡operational probability

Fault Tolerant Controller Placement

$$\min \sum_{i \in F} \psi_i y_i + \sum_{j \in N} \sum_{i \in F} \omega_{ij} x_{ij}$$

cost of deploying controllers

cost of connecting nodes to controllers

$$\text{s.t.} \sum_{\forall i \in F} x_{ij} > 0, \quad \forall j \in N$$

$$x_{ij} \leq y_i, \quad \forall j \in N, \forall i \in F$$

reliability constraint (ß = 5 9's)

$$R(G, j, I_j) \geq \beta, \quad \forall j \in N$$

$$x_{ij}, y_i \in \{0, 1\}$$

Formulation

high complexity

The Internet Topology Zoo

124 WANs

Evaluation

randomized

Algorithm

heuristic

Algorithm 1: Heuristic algorithm for FTCP.

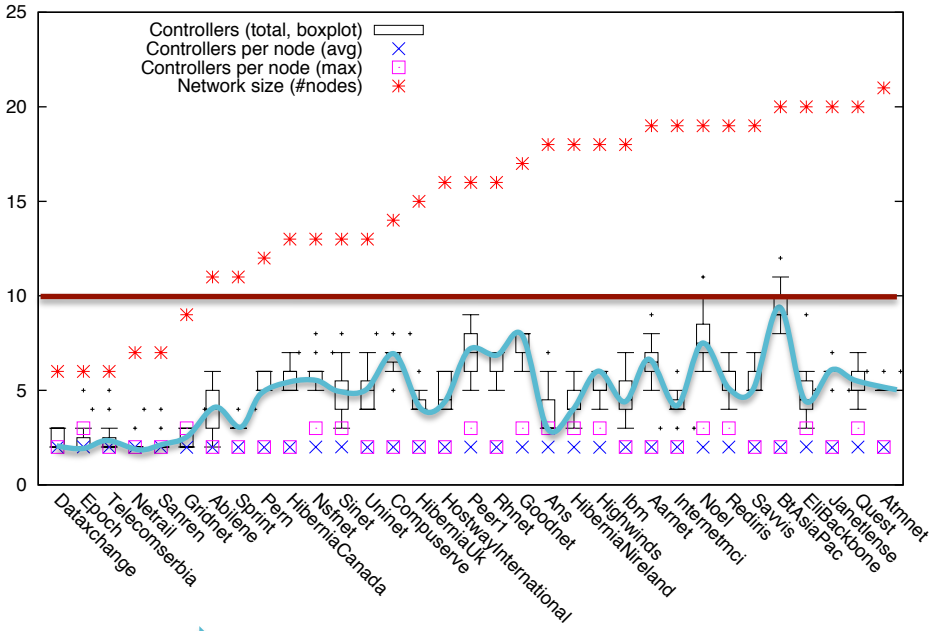
Input: Graph G, nodes N, facilities F, reliability threshold $\beta < 1$, incentive parameter $\tau > 1$

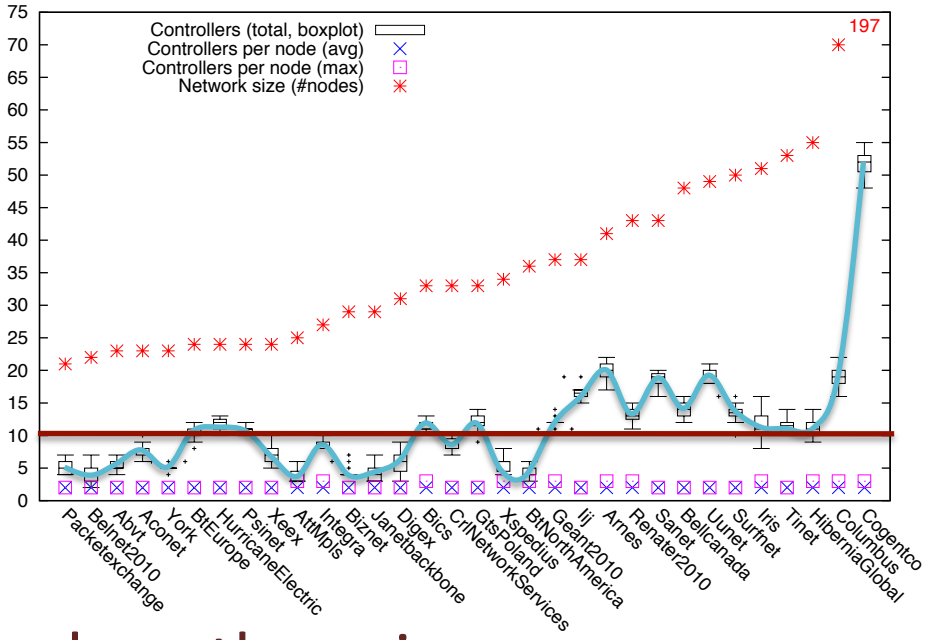
1 $S_i \leftarrow \sum_{j \in n(i)} D_j, \forall i \in F$;
2 **foreach** $j \in N$ **do**
3 $I_j \leftarrow \emptyset$; $\hat{R}_{prev} \leftarrow 0$;
4 $rank \leftarrow [i \in F]$ in reverse order of S_i;
5 **foreach** $i \in rank$ **do**
6 $I_j \leftarrow I_j \cup \{i\}$;
7 Build G' from G and I_j;
8 $f \leftarrow max\_flow(G', j_0, t)$;
9 $remove\_edge(G', u, v), \forall (u, v) : f(u, v) = 0$;
10 $\Pi_{j_0,t} \leftarrow \lambda$ disjoint paths in G';
11 $\hat{R} \leftarrow 1 - \prod_{\forall \pi \in \Pi_{j_0,t}} \left(1 - \prod_{\forall (u,v) \in \pi} p_{u,v}\right)$;
12 **if** $\hat{R} > \hat{R}_{prev}$ **then**
13 **if** $\hat{R} \geq \beta$ **then**
14 $I_j \leftarrow \{k \in I : (\exists \pi \in \Pi_{j_0,t} : k \in \pi)\}$;
15 break;
16 $\hat{R}_{prev} \leftarrow \hat{R}$
17 $S_i \leftarrow \tau S_i, \forall i \in I_j$;

Results

- **How many** controllers?

Mode	Median	75-pctl	Mean	Std Dev
5	6	10	8.2	7

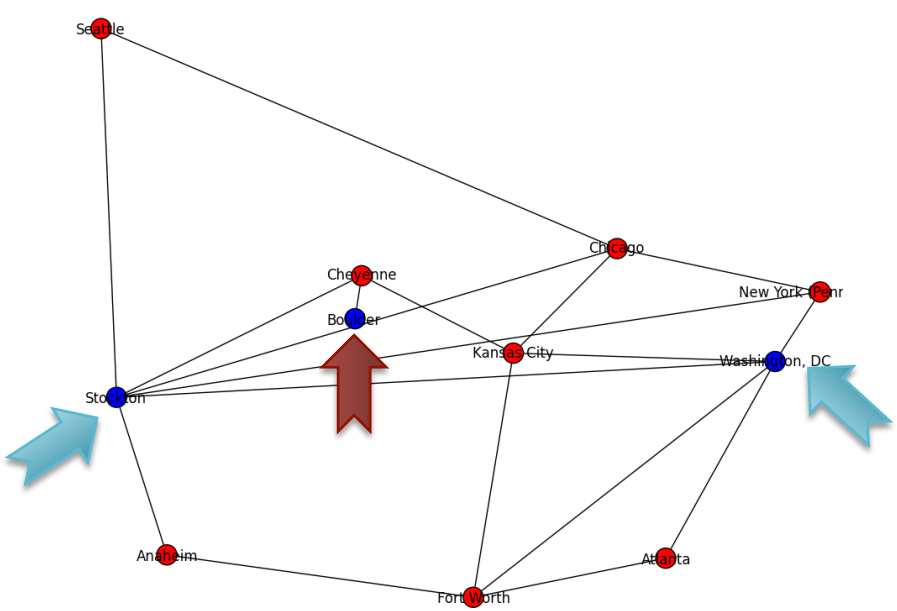




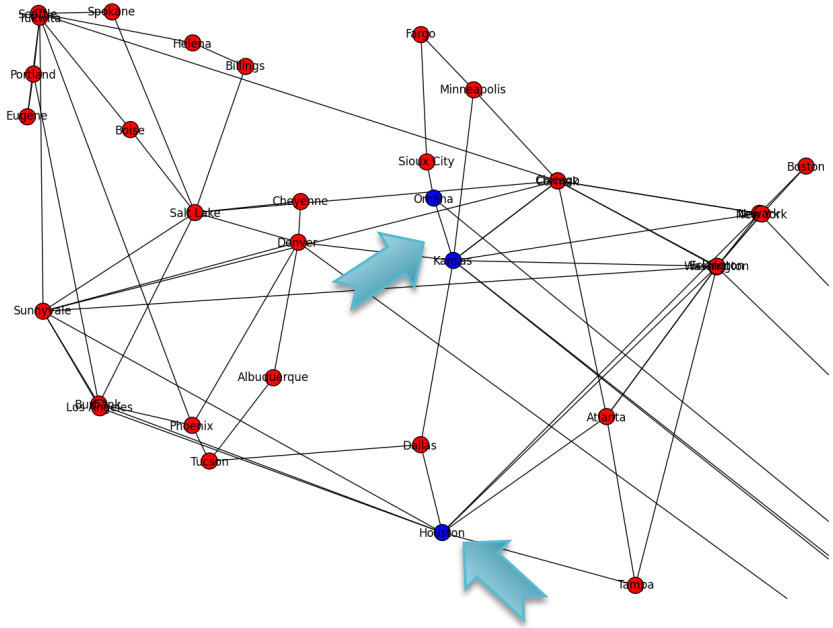
- It **depends**, more on topology than size
- In **75%** of networks with certain degree of redundancy**, ≤10 controllers** provide five 9's

Results

- **Where?**



Sprint



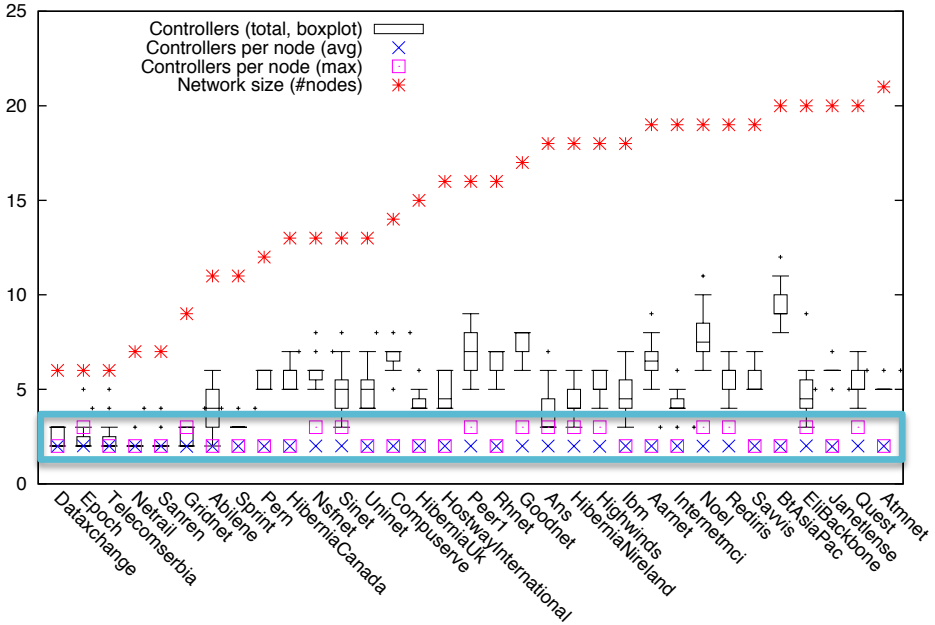
BtNorthAmerica

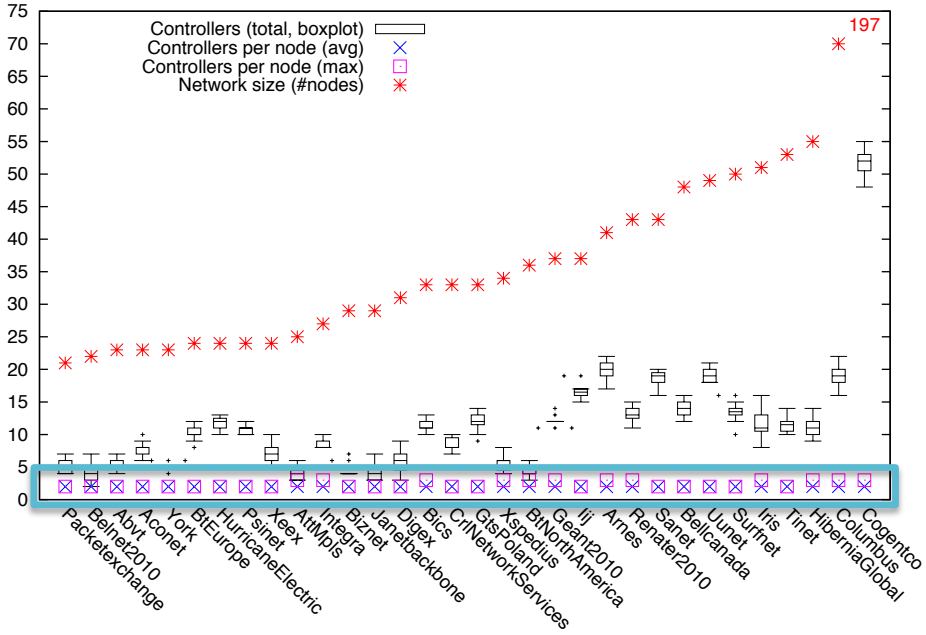
Usually in central facilities with high connectivity

In facilities with poor connectivity if necessary

Results

- **Controllers per node?**





➡ **Avg ≈ 2, Max = 3**

➡ **R > five 9's** for **most nodes**

Ř	5 9's	6 9's	7 9's	≥ 8 9's
Nodes	2.26%	44.38%	47.15%	6.21%

Conclusion and Ongoing Work

If

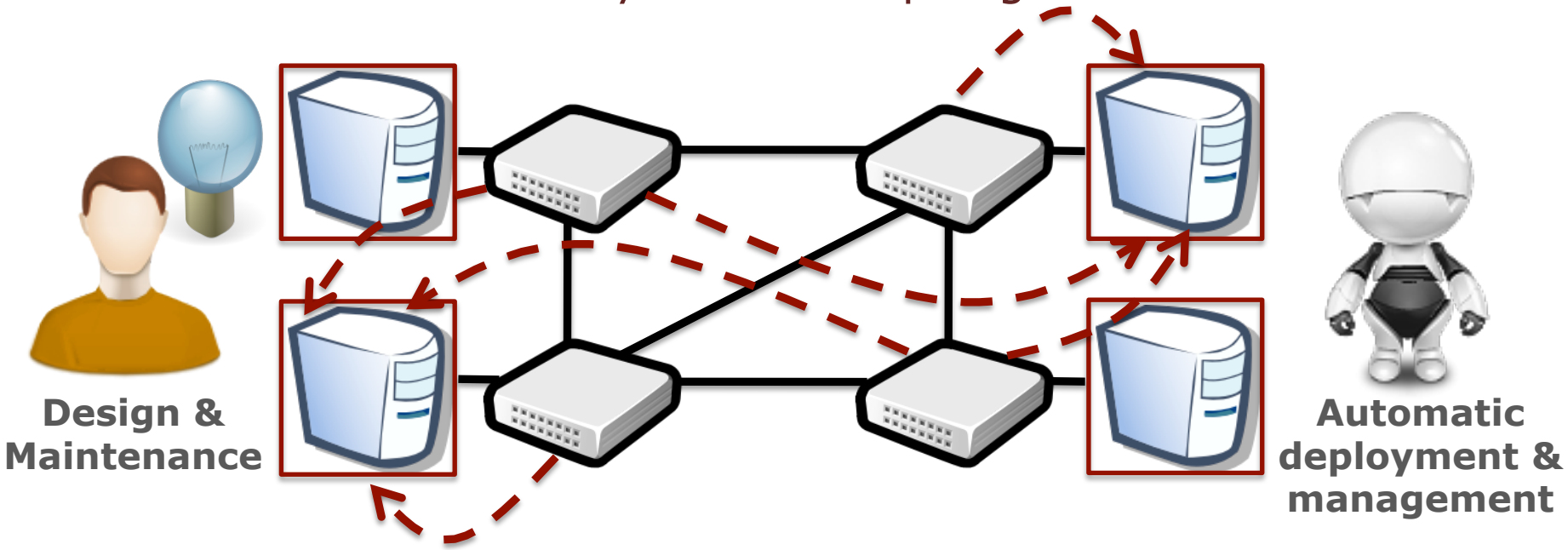
deploy the appropriate number of controllers

place them wisely

nodes connect to the right subset of controllers

Then

data and control planes attached with high likelihood in many network topologies



Thank you

Francisco J. Ros

http://masimum.inf.um.es

fjros@um.es