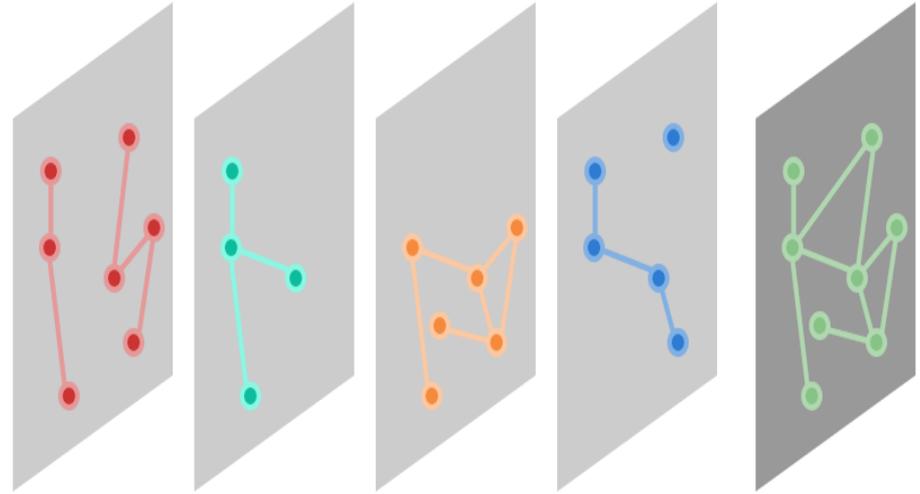


ECTQ 2015

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Comparison of single and partial-multiplex patent networks



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Comparison of single and partial-multiplex patent networks

⇒ Initial questions :

How do inventors collaborate?

How do innovation categories interact with each other?

■ European Patent Office (EPO)

- ✓ One of the two organs of European Patent Organization (EPO)
- ✓ EPO officers study European patent applications, filed by applicants, and decide whether to grant a patent for an invention
- ✓ Patents filed/granted are not restricted to European inventors

■ OECD ISIC classification

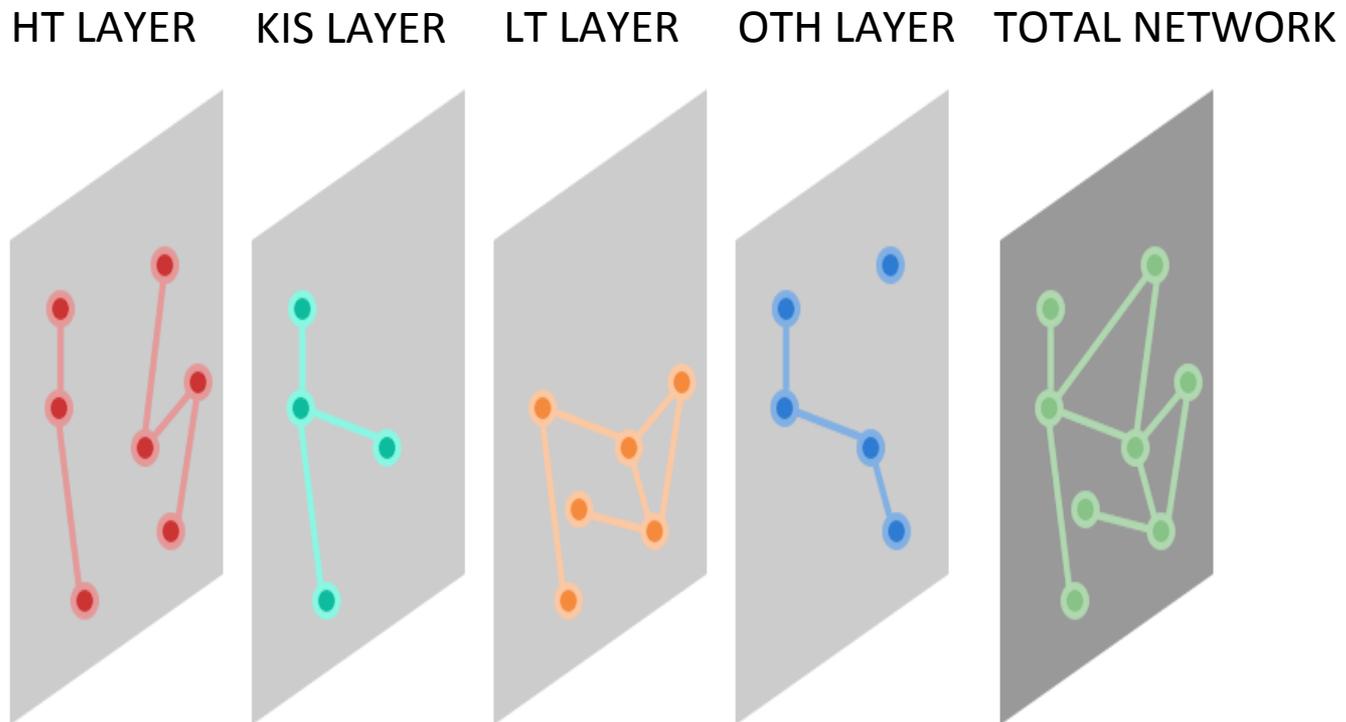
- ✓ **Manufacturing sector: high-technology (HT)/low-technology (LT):**
 - ➡ classified according to their R&D intensity
- ✓ **Service sector: knowledge-intensive services (KIS)**
 - ➡ Systemic innovation, creation and diffusion of knowledge
- ✓ **Other (OTH)**

▪ Network of patent applicants

A link between two applicants exists if they appear in at least one patent together.

▪ Four layers

according to the OECD ISIC classification (HT, LT, KIS, OTH)



Comparison of single and partial-multiplex patent networks

GOALS:

- ✓ How similar/dissimilar are the category of patent (layer) networks structurally?
- ✓ Are the most prominent nodes the same for each category of patent (layer) ?
- ✓ How the individual category of patent (layer) are affected by considering the interactions between them as a partial-multiplex network?
- ✓ Is there a category of patent (layer) which has a higher effect on others in a dynamic process?

PLAN:

A- STRUCTURAL ANALYSIS OF THE FOUR LAYERS AND THE AGGREGATED NETWORK

B- SPREADING PROCESSES ON THE FOUR-LAYERED, PARTIAL-MULTIPLEX NETWORK

PART A:

**STRUCTURAL ANALYSIS
OF THE FOUR LAYERS AND THE AGGREGATED NETWORK**

European Patent Office (1988 to 2013)

Number of patents	2,683,245
<i>of which with at least two applicants</i>	151,474 (5.6%)
Number of applicants	429,527
<i>of which collaborating</i>	123,181 (28.7%)

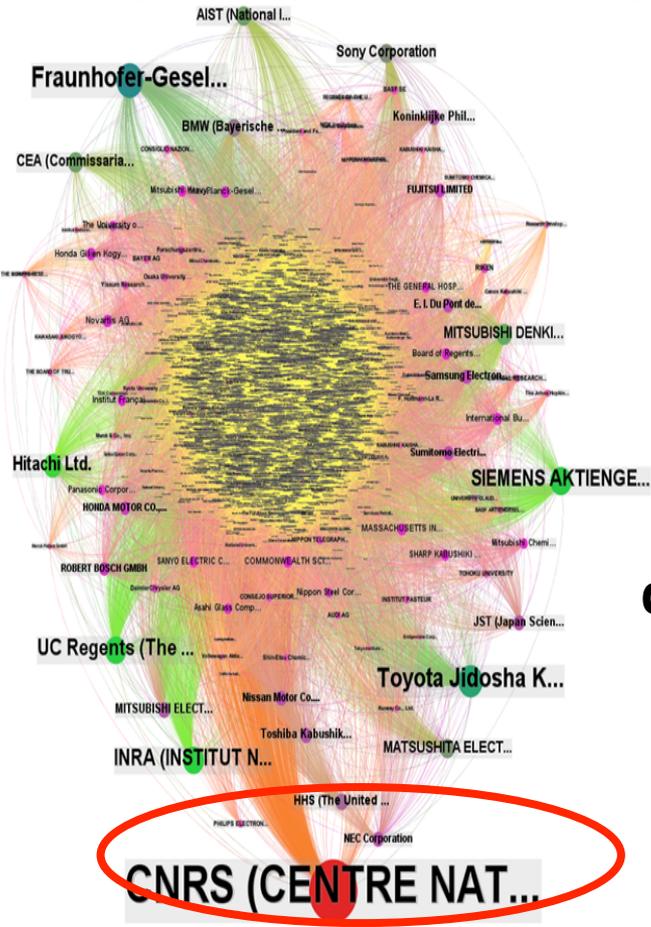
EPO patents database (July 2014 version)

Properties of the network of patents / four OECD layers

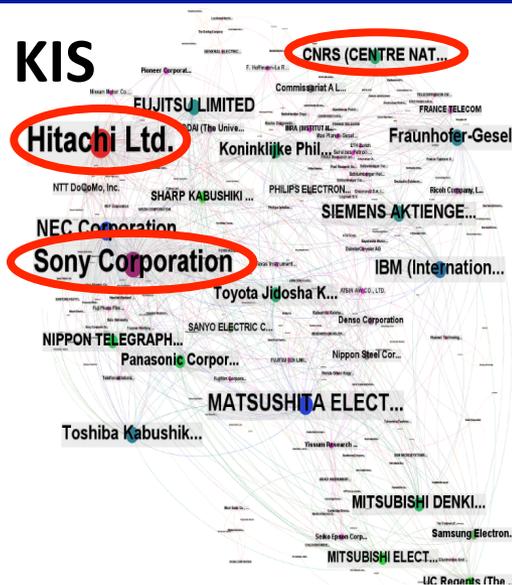
	All network	HIGH TECH	KIS	LOW TECH	OTHER
Number of applicants (nodes)	429,527	30,903	574	13,421	719
Number of collaborating applicants	123,181 (29%)	30,903 (100%)	438 (76%)	10,171 (76%)	514 (72%)
Network links (patents)	151,474	59,524	896	24,367	823
Network density	0.00002	0.0001	0.0094	0.0005	0.0062
Network transitivity (clustering coefficient)	0.77	0.53	0.54	0.39	0.44
Nodes in largest connected component (LCC)	34,214 (28%)	30,053 (97%)	359 (63%)	9500 (71%)	346 (48%)
Links in largest connected component	69246	58614	828	23762	707

TSOUCHNIKA et al., 2015

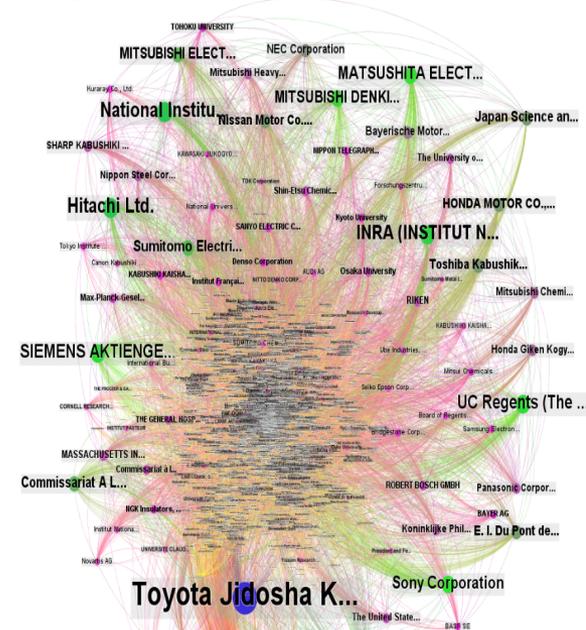
a. HIGH TECH



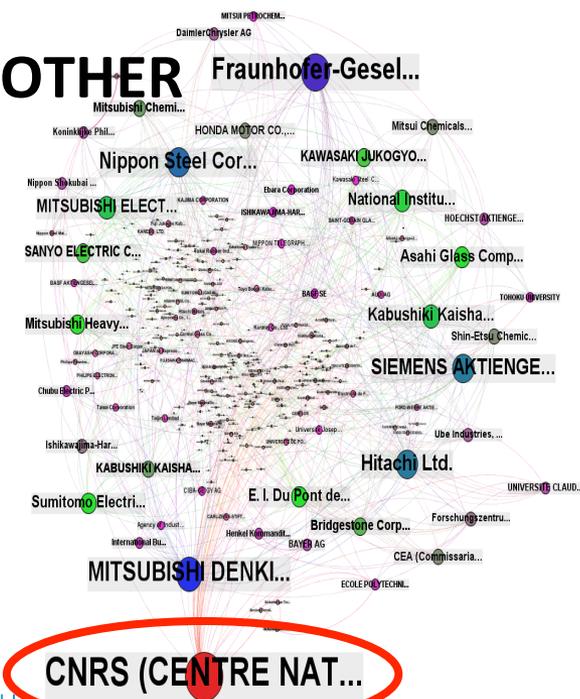
b. KIS



c. LOW TECH



d. OTHER

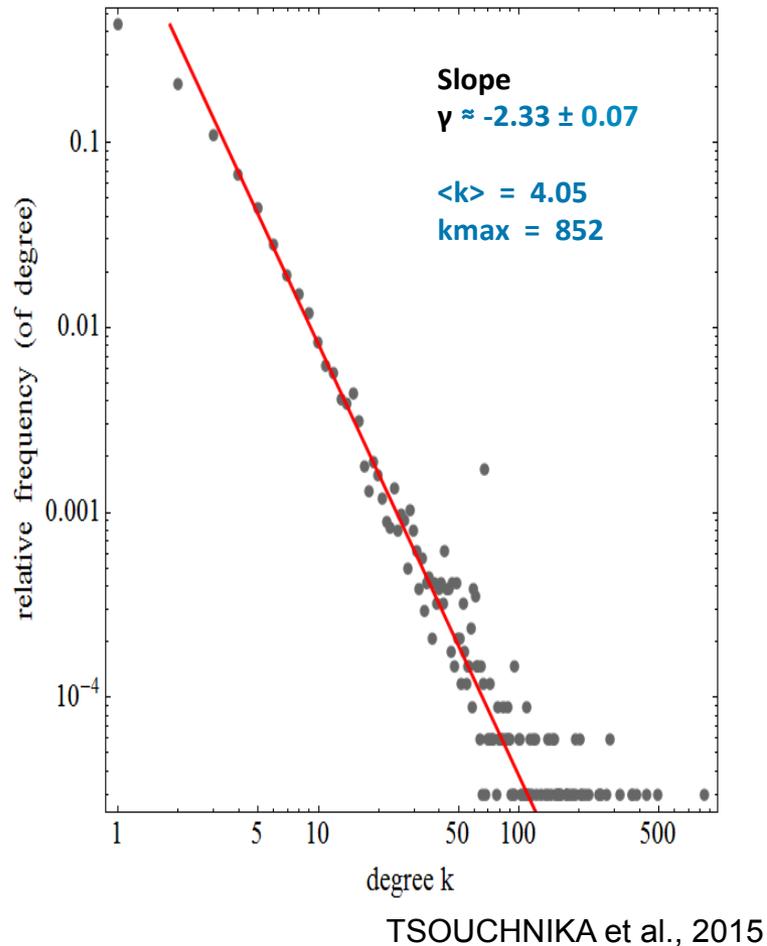


CNRS (CENTRE NAT...

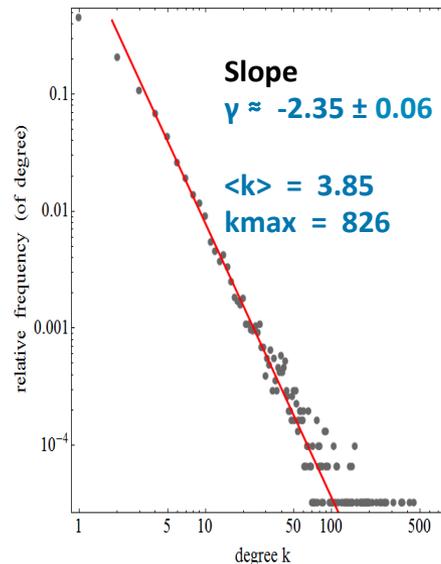
TSOUCHNIKA et al., 2015

Probability density of degree in the Largest Connected Component (LCC)

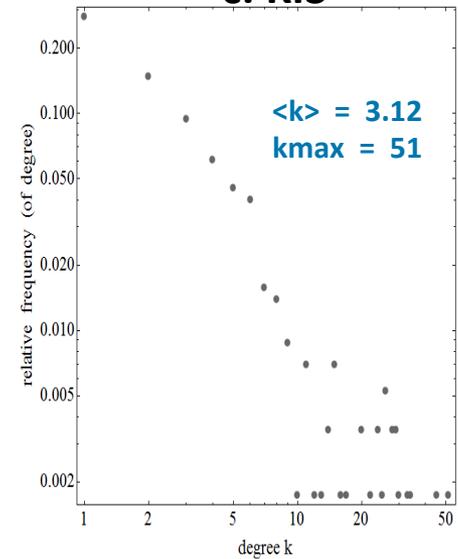
a. TOTAL NETWORK



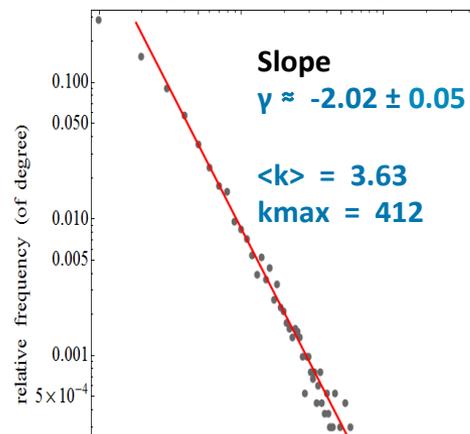
b. HIGH TECH



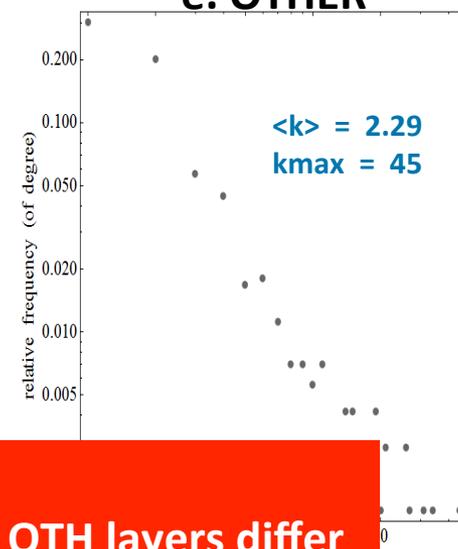
c. KIS



d. LOW TECH



e. OTHER



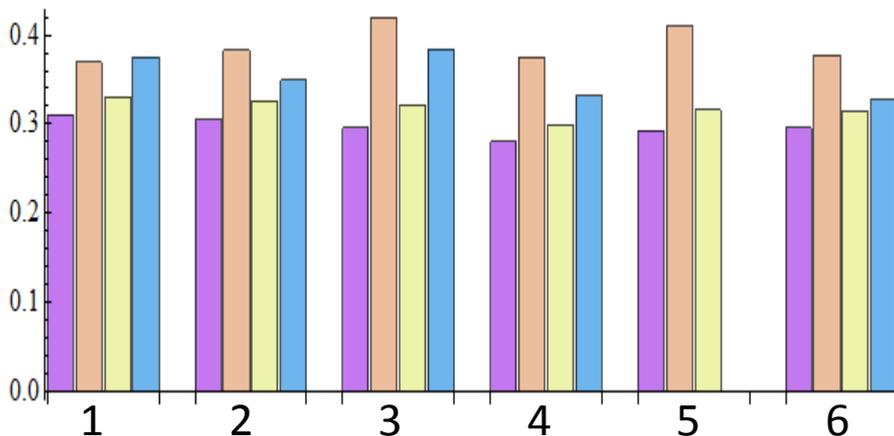
Result 1:

HIGH TECH and LOW TECH layers similar in structure / KIS and OTH layers differ

Centralities of six representative applicants (nodes) in the four layers

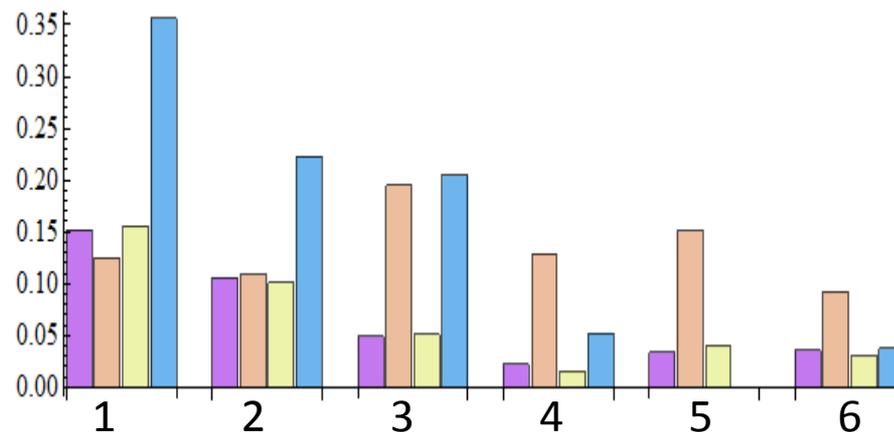
a. Closeness

HT KIS LT OTH



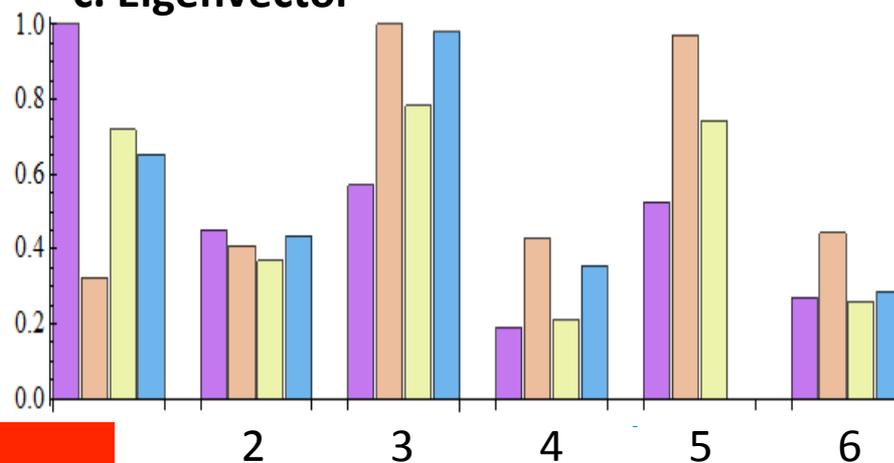
b. Betweenness

HT KIS LT OTH



c. Eigenvector

HT KIS LT OTH

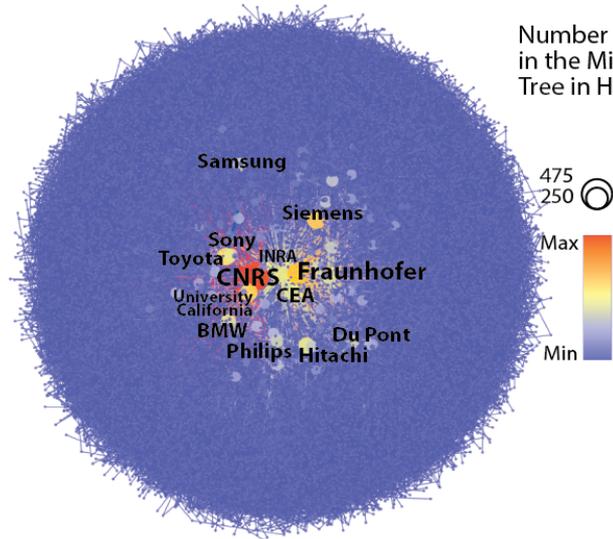


1. CNRS
2. Fraunhofer-Gesellschaft,
3. Hitachi,
4. IBM,
5. Sony
6. Philips

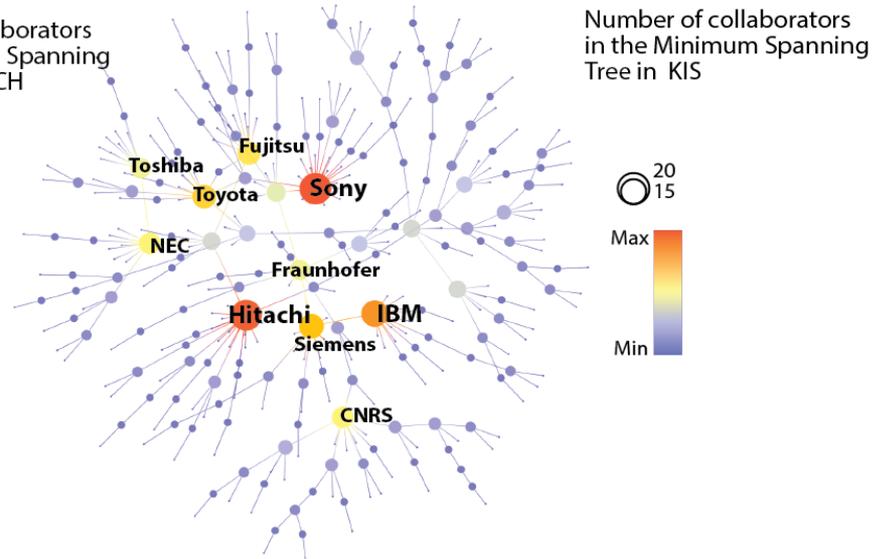
Result 2:
KIS is the only with different prominent nodes

Minimum spanning trees

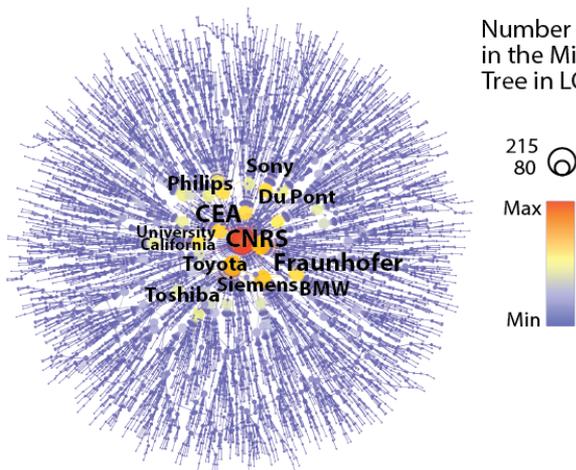
HIGH TECH



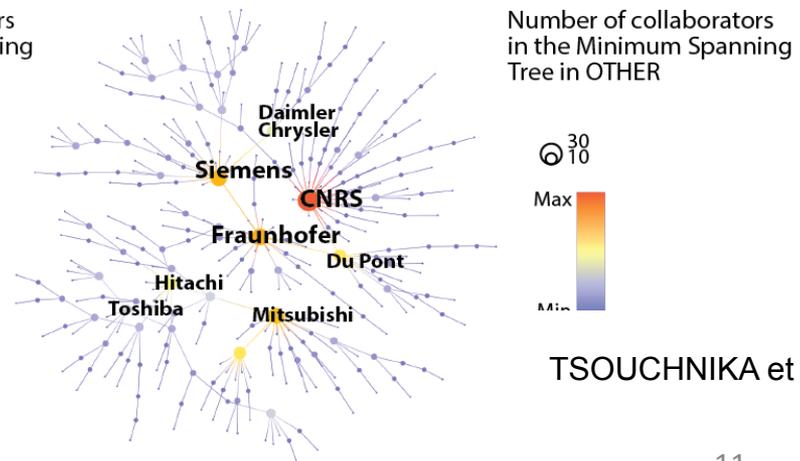
KIS



LOW TECH



OTHER



TSOUCHNIKA et al., 2015

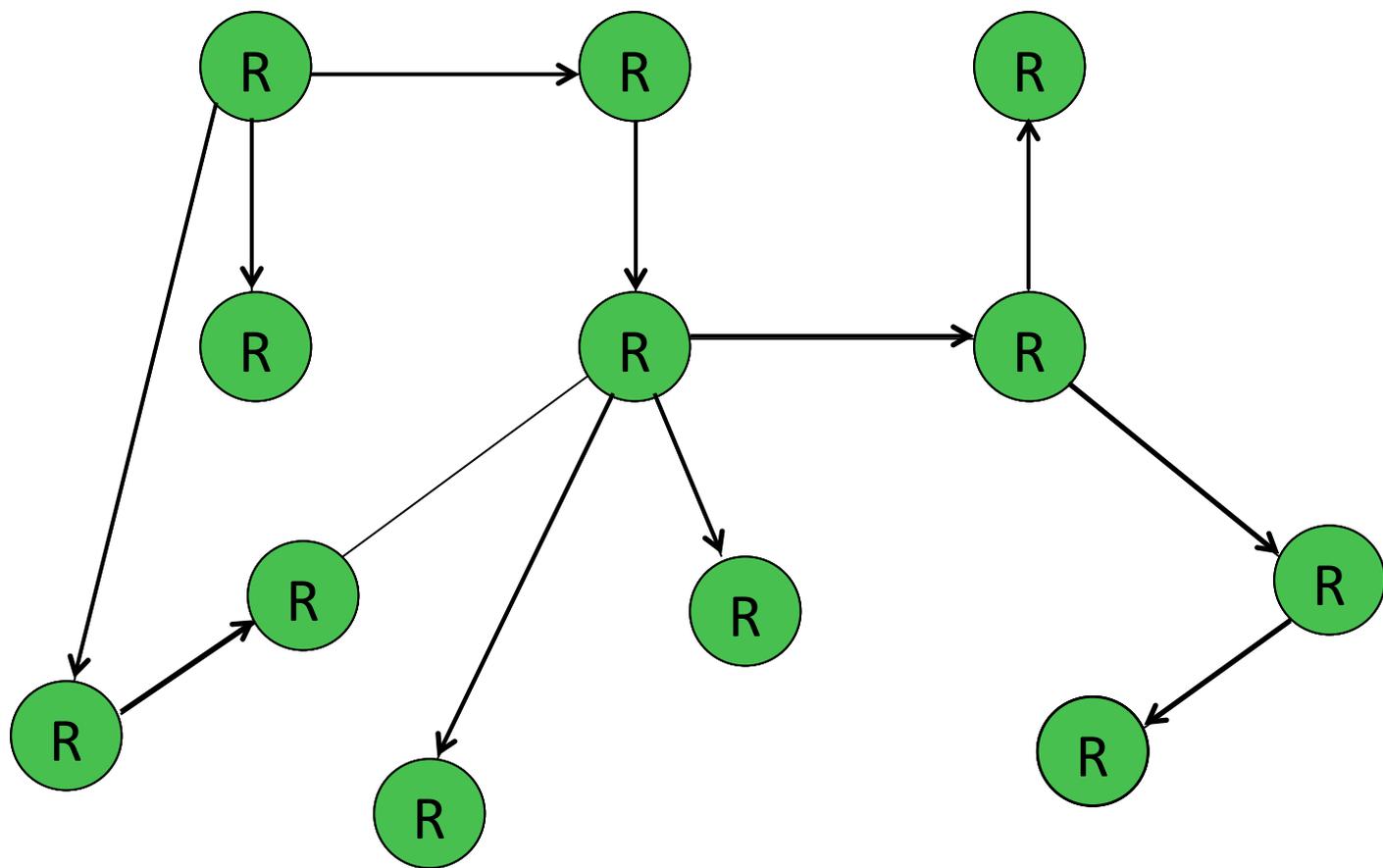
PART B:**STUDY OF SPREADING PROCESSES ON THE FOUR-LAYERED
PARTIAL-MULTIPLEX NETWORK**

SIR model features

Characteristics:

- **A probability of infection determined by the network topology**
 - proportional to the weight of their link
 - => how many times two nodes have collaborated in a patent
 - inversely proportional to the weighted degree of the target node
 - A multiplicative factor (range $[0,1]$) : intensity of the simulated crisis
 - => In all our simulations we chose this factor to be 1
- **A varying recovery rate (RR) parameter**
 - => **number of time steps it takes an infected node to recover.**

SIR model example

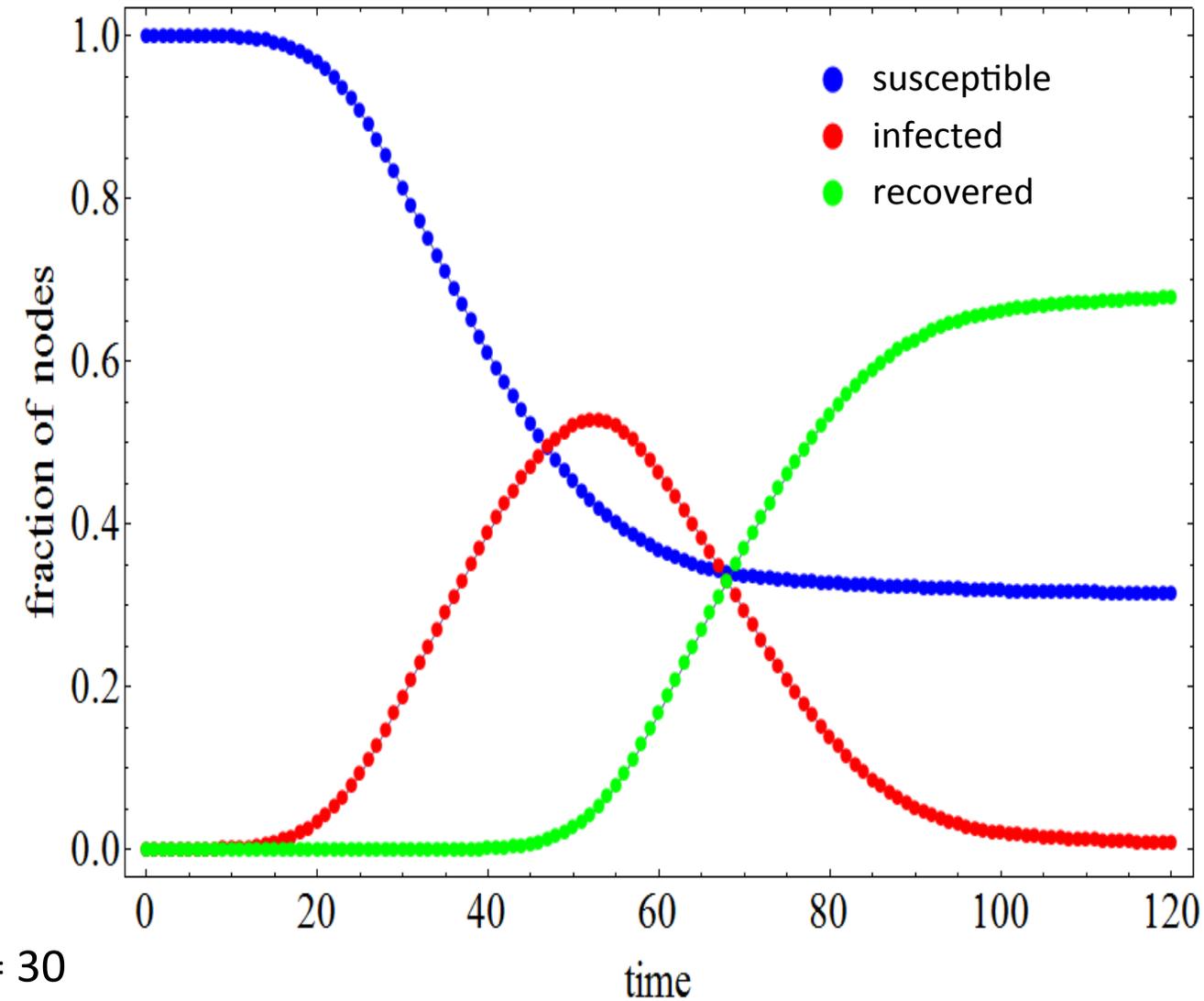


S Susceptible

I Infected

R Recovered (or Removed)

SIR process on the total network



RR = 30

Average of 300 realizations

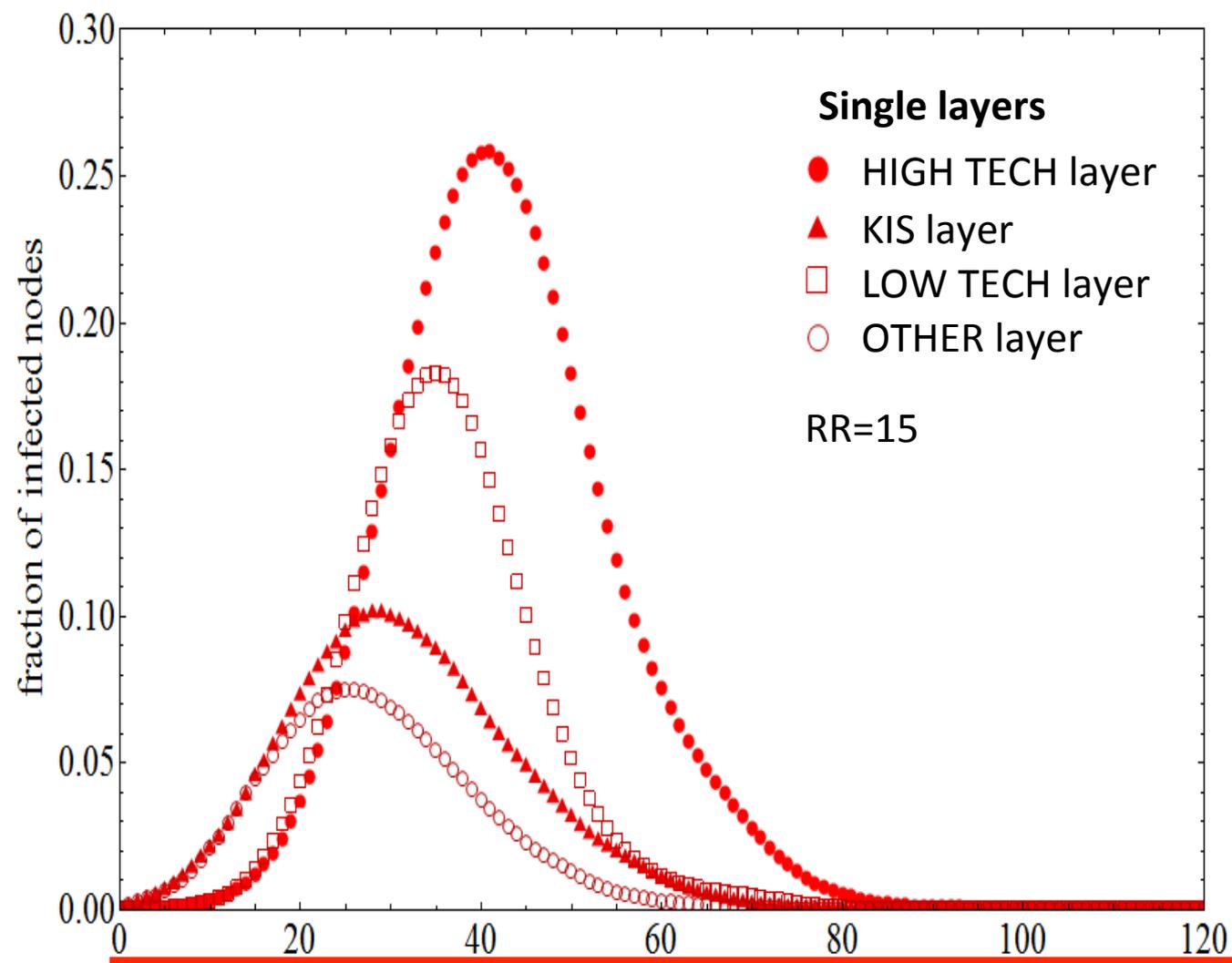
TSOUCHNIKA et al., 2015

SIR process on the 4 independent layers' networks

- 1- Simulate SIR spreading process on each layer, separately
- 2- Compare the behavior of the separate layers (HT, KIS, LT, OTH)

1- SIR process on the 4 independent layers' networks

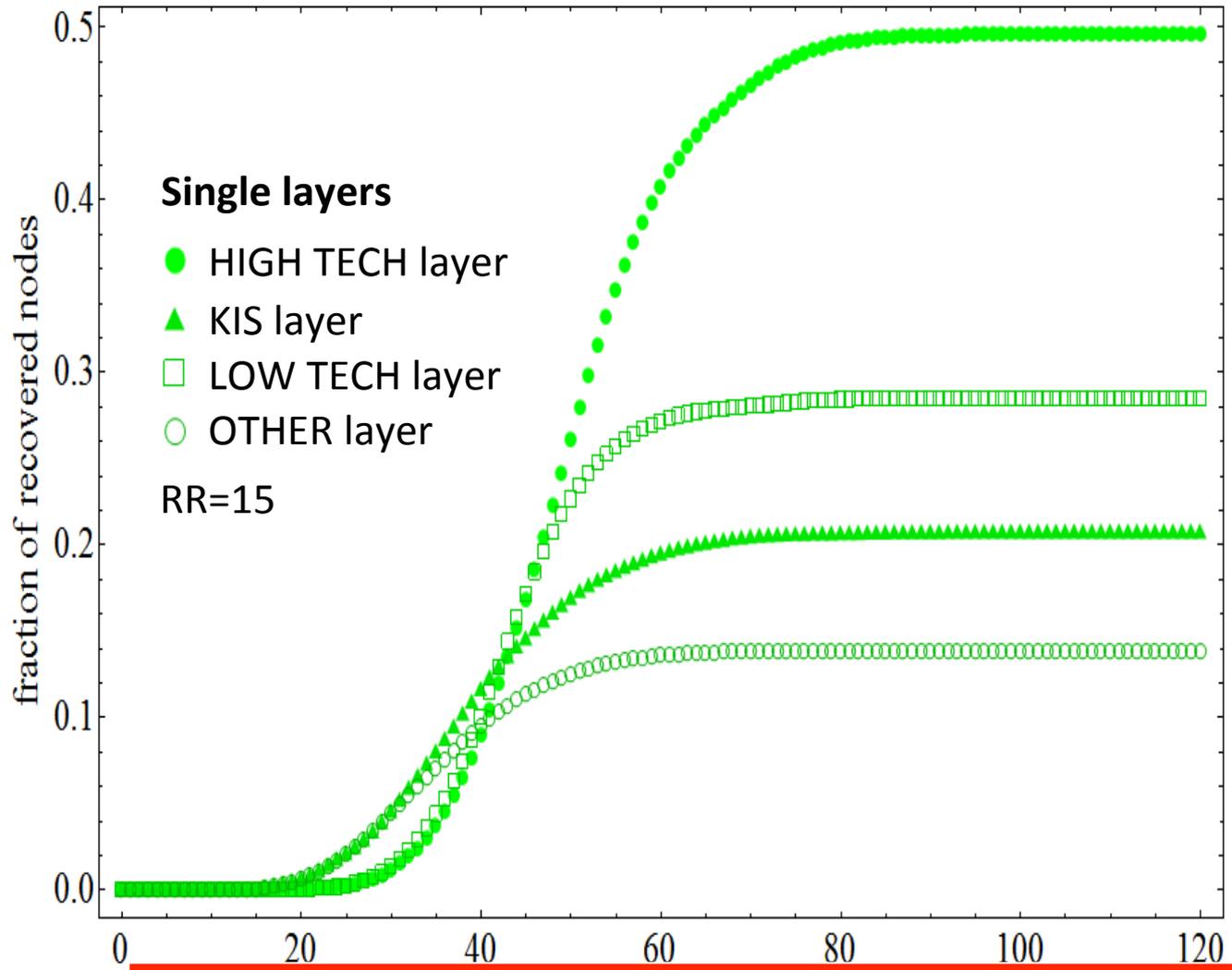
Infected nodes



Result 3: The infection spreads faster on the KIS and OTHER layers

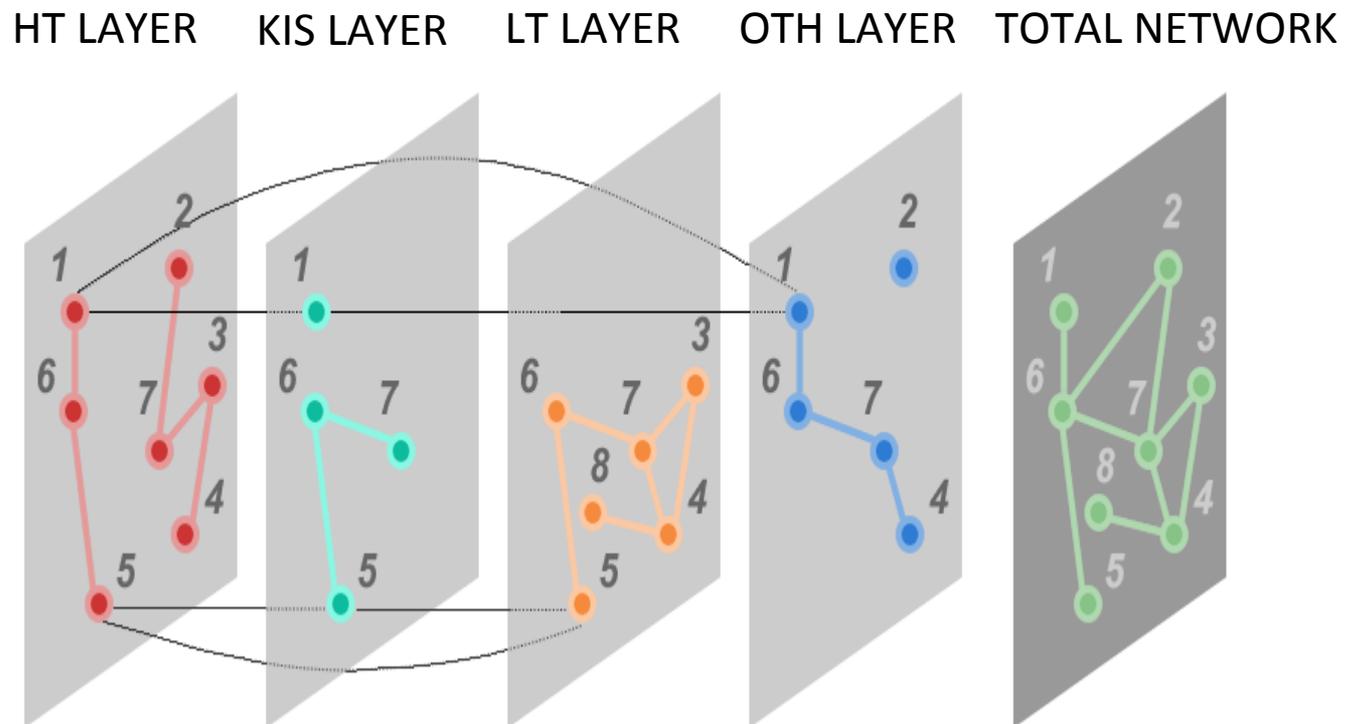
1- SIR process on the 4 independent layers' networks

Recovered nodes



Result 4: KIS and OTHER layers recover faster than HT and LT

Combination of the four layers => partial-multiplex network



Inter-layer connections :

⇒ Every node is linked to itself for all the layers that it exists in.

⇒ Examples: node 1, node 5

Combination of the four layers => partial-multiplex network

■ Six cases:

- Partial-multiplex networks:

- ✓ Case 1: Start the process from a randomly chosen layer
- ✓ Case 2: Start the process from the HT layer
- ✓ Case 3: Start the process from the KIS layer
- ✓ Case 4: Start the process from the LT layer
- ✓ Case 5: Start the process from the OTH layer

- Single layer case:

- ✓ Case 6: Single layer => Treat each layer as separate, as previously

■ Measures:

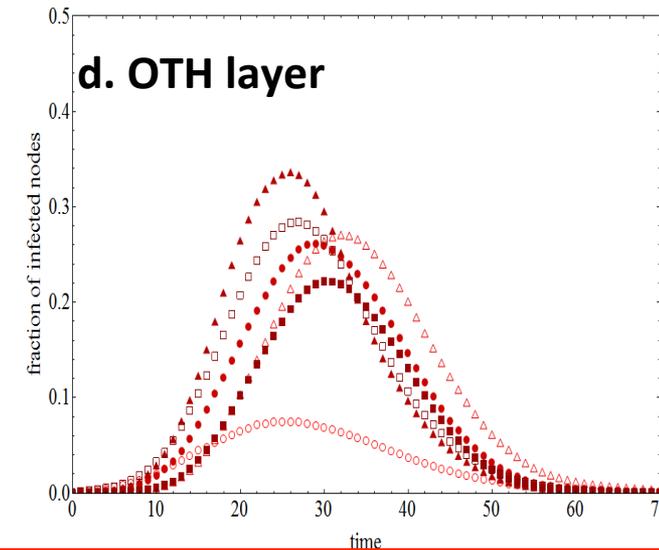
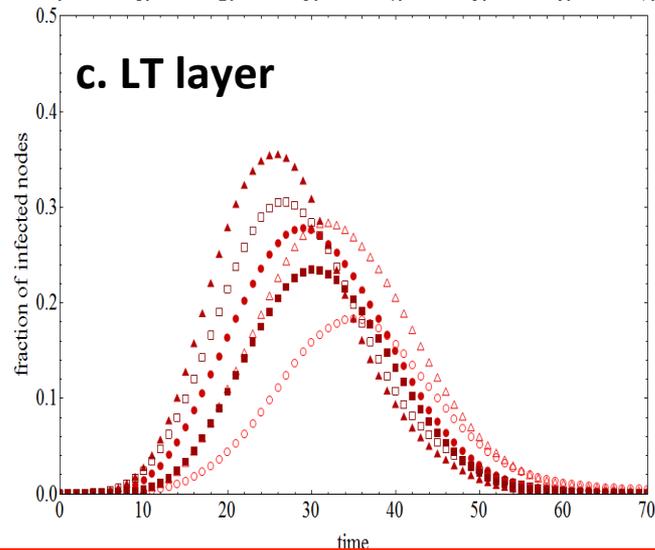
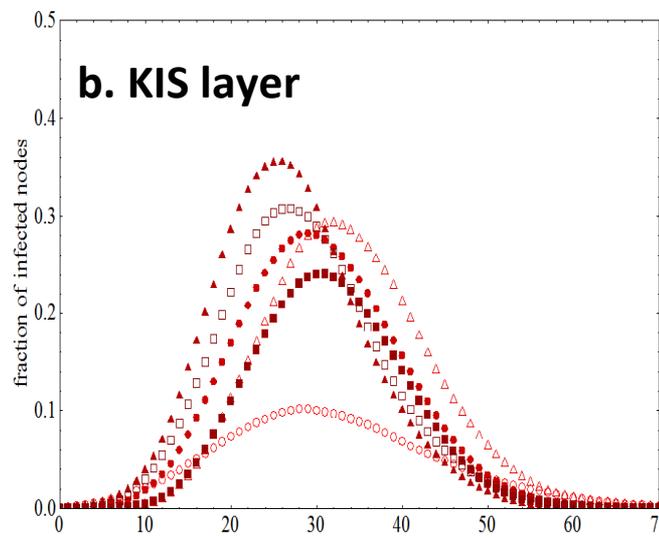
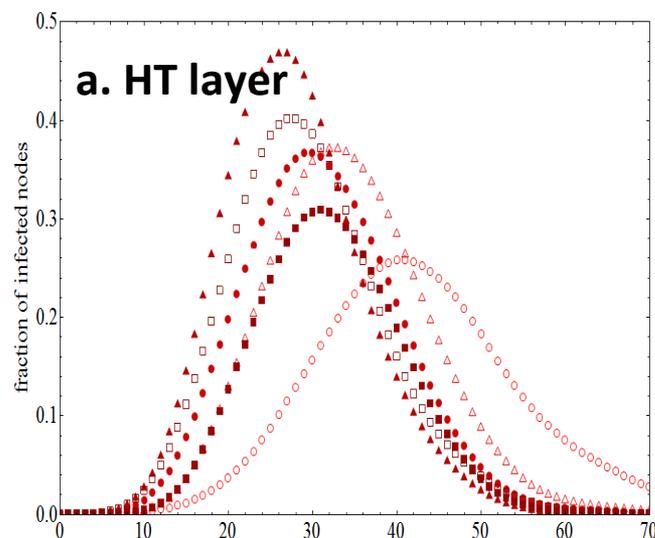
⇒ Monitoring of the fraction of infected nodes present in each layer

⇒ Comparison of the five **partial-multiplex network** cases to the **single layer case**

■ Parameters:

In the case shown, we use **RR = 15** and (inter-layer probability) **$p_{\text{inter}} = 0.8$**

Partial-multiplex network spread infection on each layer



○ single layer case

Partial-Multiplex:

● seed from random layer

△ seed from HT

▲ seed from KIS

■ seed from LT

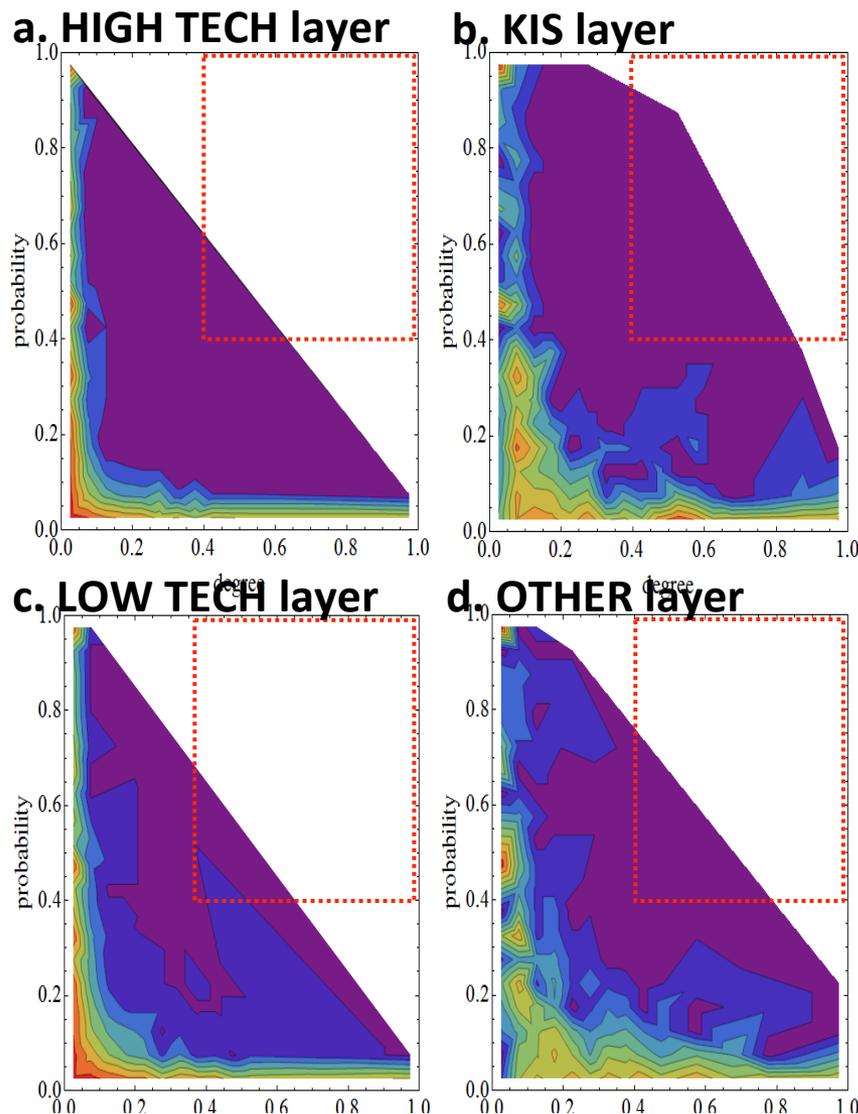
□ seed from OTH

Average of 300 realizations

Result 5: Infection spreads faster on partial-multiplex network

Result 6: Infection spreads faster on all four layers when the initial seed is on the KIS layer

Contour plot of node degree and probability of infection



KIS and OTHER layers surpass HIGH TECH and LOW TECH layers in nodes that exhibit relatively high degree along with high probability to be infected => explain the high role of KIS

Results

Structural analysis

- 1- LOW TECH and HIGH TECH layers similar in structure / KIS and OTHER layers differ
- 2- Of the four layers, KIS is the only with different prominent nodes

Spreading processes

- 3/4- On KIS and OTHER the infection spreads faster
- 5- Infections spread faster on partial-multiplex network
- 6- KIS accelerates the spreading of the infection on all layers

Conclusions

- KIS and OTHER layers are thematically more spread in the whole network
- they are not so numerous but permit the connections between fields
- they also make bridge between specialized patents in HIGH TECH and LOW TECH

⇒ **Perspectives: add the geographic dimension in these simulations...**

Thanks for your attention...

grazie per la vostra attenzione...

