20 years of COORDINATION Technologies

State of Art and Perspectives

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Goal

- Nowadays, coordination is more relevant than ever before, and will increasingly be so in the future
  - many driving applications: Blockchain, Internet of Things, *Everything*-as-a-Service, Workflow Management Systems, …
- Thus: what is the status of coordination **technologies**?
  - are they industry-ready? or what is missing?
  - which are their “killer apps”? or which research directions are the most explored?
- Aim: provide ***fertile ground for discussion on future directions***

Outline

- Method
- Overview data
- Focus on technologies
- Insights on data
- Perspectives

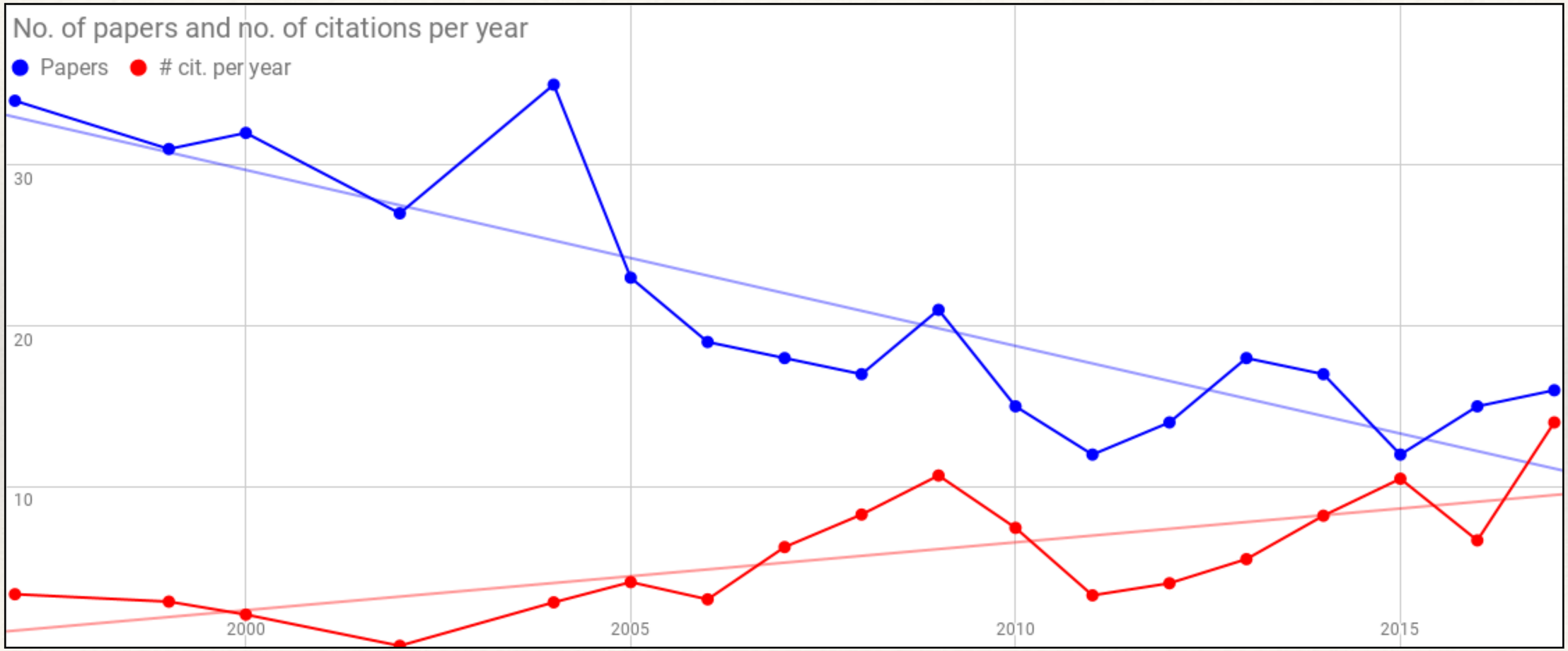
Method

- Look back at the past 20 years of COORDINATION
  - conference proceedings as available from **SpringerLink**
  - data provided by companion service **BookMetrix**
- Incrementally **filter** papers:
  1. remove papers NOT about a technology
  2. remove papers which provide NO reference to software artefacts
  3. for surviving papers, check **status** of proposed technology
  4. for surviving papers, **play** with the technology

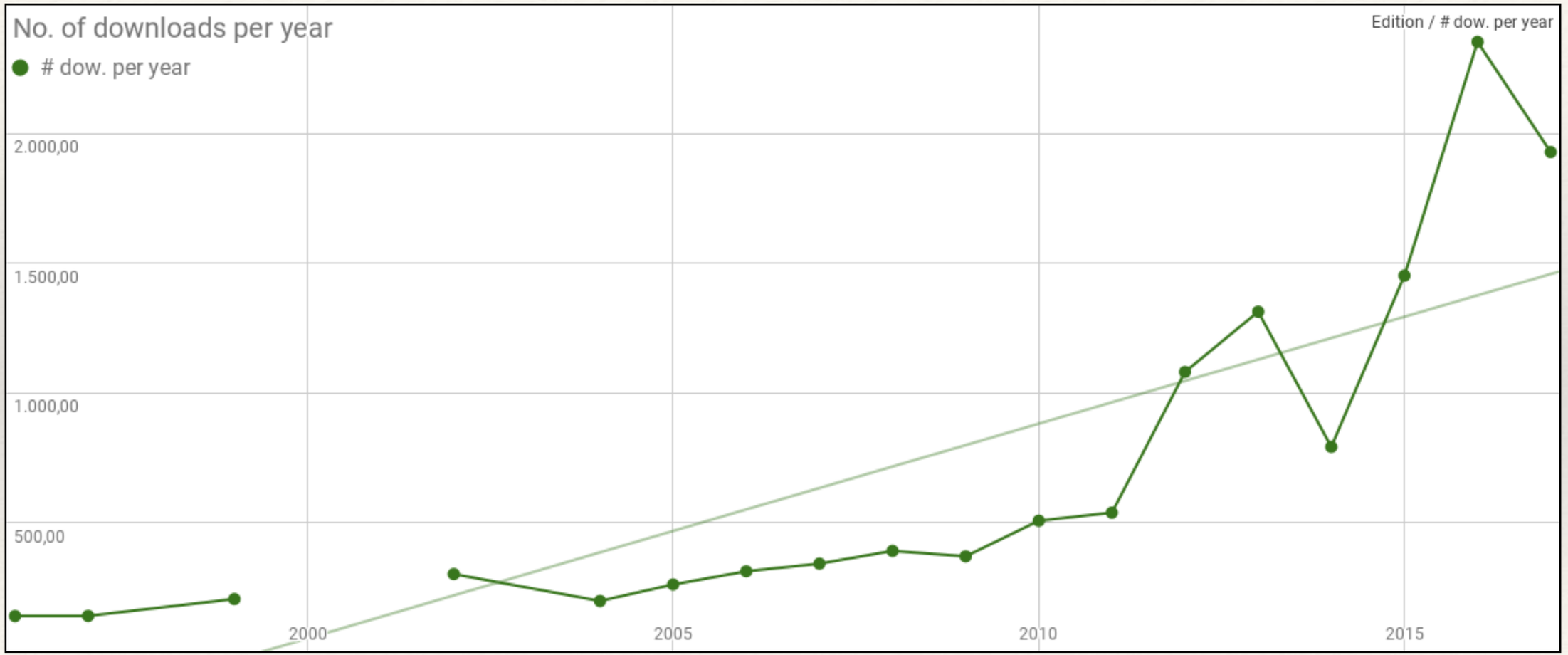
Method: filters

- “Status”
  - last update to source code
  - documentation
  - build process / deployment successful
- “Play”
  - run tests / demos
  - implement simple scenario (i.e. prod-cons, master-workers)

Overview: #papers, citations/year



Overview: downloads/year



Overview: raw numbers

- Avg citations/year ~ 5.5
- Avg downloads/year ~ 700
- Most cited paper about tech? 7 / 19 ~ **37%**
- Most downloaded paper about tech? 8 / 19 ~ **42%**
- Tech papers? 47 / 390 ~ **12%**

Focus on Tech: evolution

- Based on papers passing filter **§2** (there is a reference to sw artefact)
- New millenium as separator (empirically)
  - before (1996-2000): many technologies, some of which still available (i.e. Moses, Piccola), some evolved into others actively developed (i.e. ACLT –> TuCSoN, Manifold –> Reo)
  - after (2001-2017): less technologies, but more alive (i.e. Reo, Klaim and Lime families)

Focus on Tech: *working* tech

Based on technologies passing filter §4 (software can be obtained)

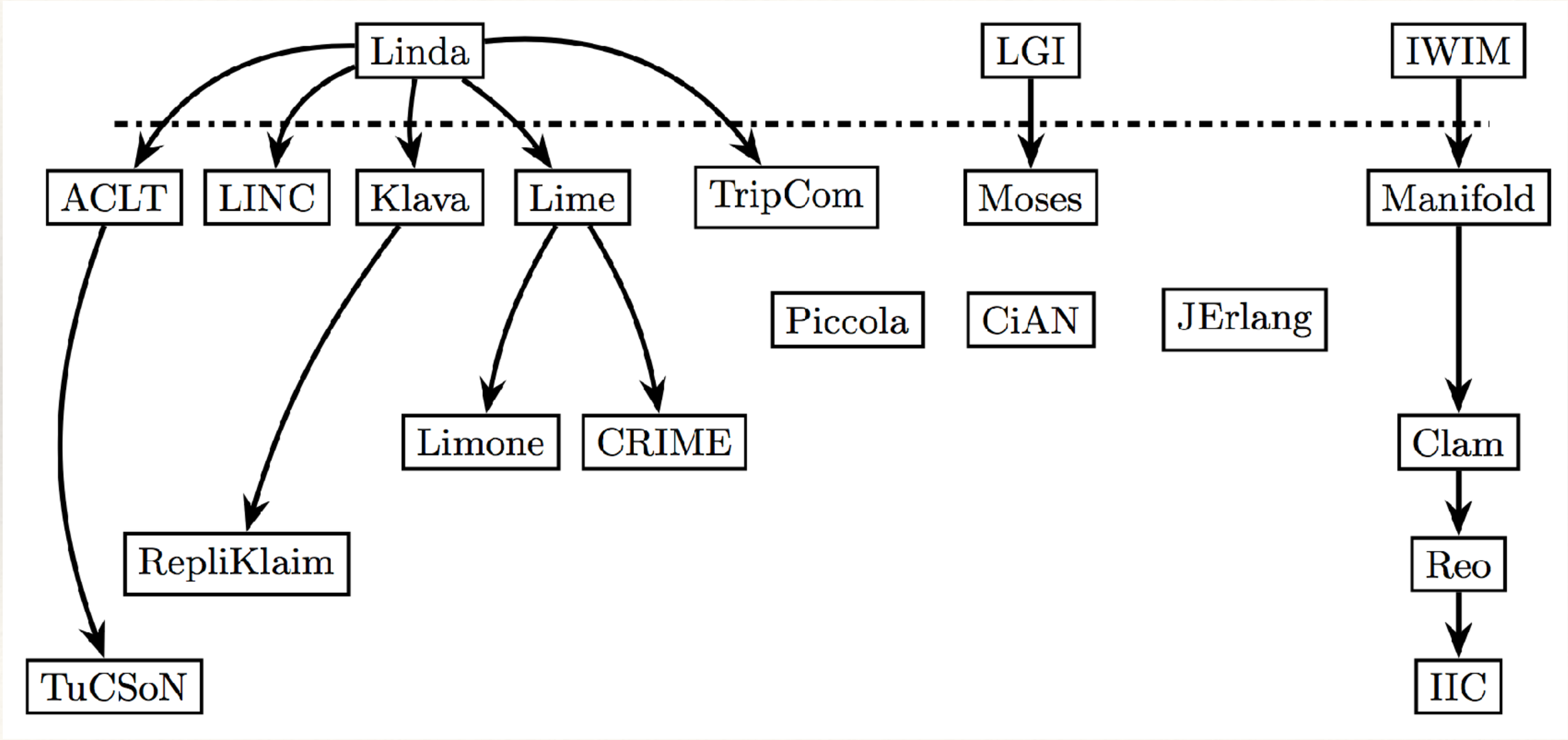
Name	Last update	Health	Documentation	Source code	Build	Deployment
TuCSoN	2017	Actively developed	Available	Available	Successful	Successful
Moses	2017	Actively developed/maintained	Available	Unavailable	—	Successful
JErlang	2017	Discontinued	Poor	Available	Failed	—
IIC	2015	Discontinued	Poor	Available	Failed	Successful
Reo	2013	Actively developed	Available	Available	Successful	Partially successful
TripCom	2009	Discontinued	Partially available	Available	Successful	Successful
CiAN	2008	Discontinued	Available	Available	Successful	Successful
Piccola	2006	Discontinued	Available	Java only No Smalltalk	Successful	Successful
CRIME	2006	Discontinued	Unavailable	Unavailable	—	Successful
Klava	2004	Discontinued	Poor	Available	Successful	Successful
X-Klaim	2004	Discontinued	Available	Available	Failed	—
Limone	2004	Discontinued	Unavailable	Available	Failed	—
RepliKlaim	—[a]	—[a]	Unavailable	Available	Successful	Successful

[a] There is no publicly available code repository, thus no information about latest commits.

Focus on Tech: success stories

- TuCSoN, Moses, and Reo stand out
  - still actively developed / maintained
  - decent to good documentation
- TripCom, CiAN, Piccola notable followers
  - apparently discontinued but still in good shape
- LINC commercial success
  - not reported in table as proprietary software [LINC at Bag-Era, 2016]

Insights: a family tree



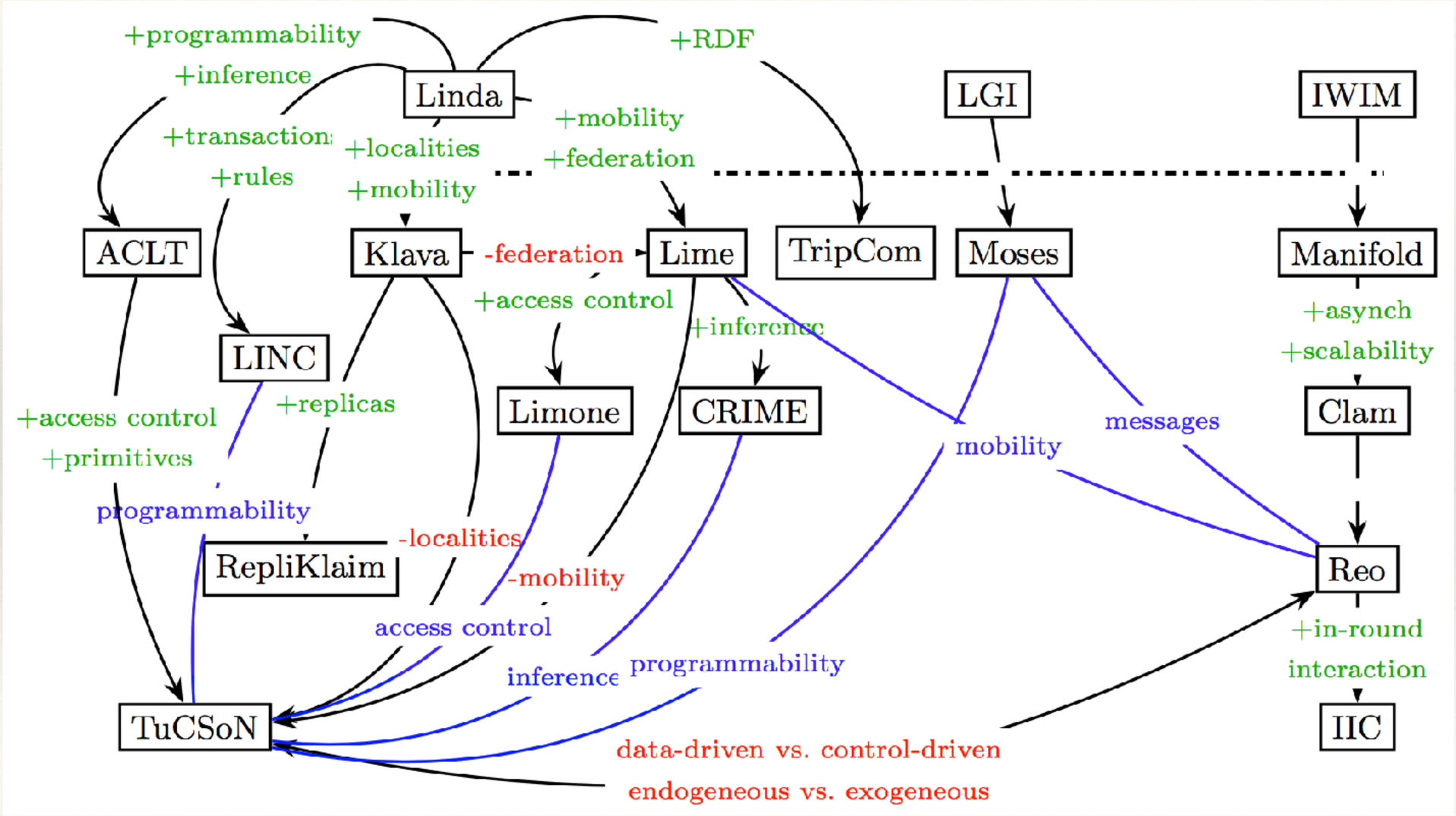
Insights: a family tree

- Most technologies still alive stem from two “archetypal” models:
  - **Linda** [Gelernter, 1985]
    - descendants diverge in many ways, according to reserch goal / application scenario
    - TuCSoN, Klaim family, Lime family, LINC and TripCom
  - **IWIM** [Arbab, 1996]
    - tree is much more linear
    - from Manifold to IIC technologies are similar

Perspectives: *integration* as key?

- Interesting fact: almost no interaction between “IWIM tree” and “Linda tree”
  - quite natural given diversity of approaches
    - control-driven vs. data-driven
    - exogeneous vs. endogeneous
- ***Integration*** of the two may be the key to industry?
  - TuCSoN made an attempt with ReSpecT [Omicini, 2007]
    - Linda-like coordination, but tuple spaces have programmable behaviour
    - change behaviour –> change outcome of coordination process

Insights: contamination



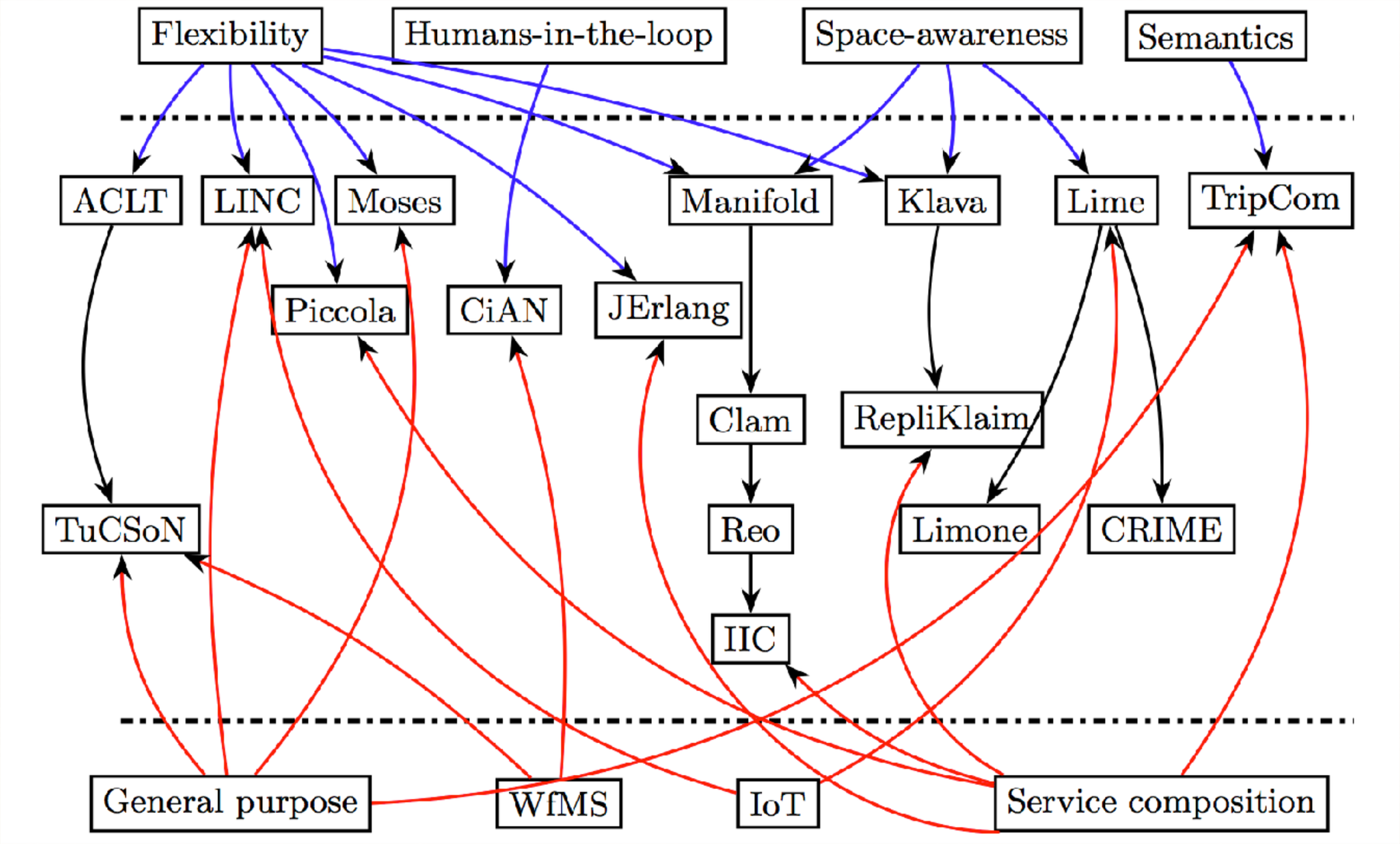
Insights: contamination

- Quite naturally, many interactions within the Linda tree
  - Klaim and Lime families both focus on mobility, but differ in the way localities are modelled and put in relationship
  - LINC and TuCSoN both provide coordination rules and transactionality, besides additional primitives, but diverge in semantics and supporting mechanisms
- Interesting fact: few but crucial Linda – IWIM interactions
  - Moses interactions rules – TuCSoN reactions, Reo – Moses message passing, CRIME – TuCSoN logic tuples, Reo – Lime – Klaim mobility as first class

Perspectives: *killer* features?

- A few features are pervasive:
  - ***programmability*** of interaction/coordination rules
  - ***access control***
  - ***mobility***
- May be the key to unlock the Internet of Things?
  - together with ***scalability*** (RepliKlaim) and ***inference*** capabilities (TuCSoN, CRIME)
  - considering the Web of Things and the Internet of Intelligent Things, too [Guinard et al, 2011] [Arsénio et al, 2013]

Insights: drivers / applications



Insights: drivers / applications

- Mostly, two drivers for development:
  - ***flexibility***: customise coordinative behaviour to suit heterogeneous needs and increase expressiveness (TuCSoN, LINC, Moses)
  - ***space-awareness***: make processes / coordination media aware of distribution (Reo, Klaim and Lime families)
- Mostly, ***service composition*** as preferred application
  - Reo and Klaim families, TripCom, even Piccola
  - LINC and Lime family further specialise in IoT deployments (IoT-enabled services)
  - CiAN further specialise in workflow management (services + humans)

Perspectives: *IoT* as killer-app?

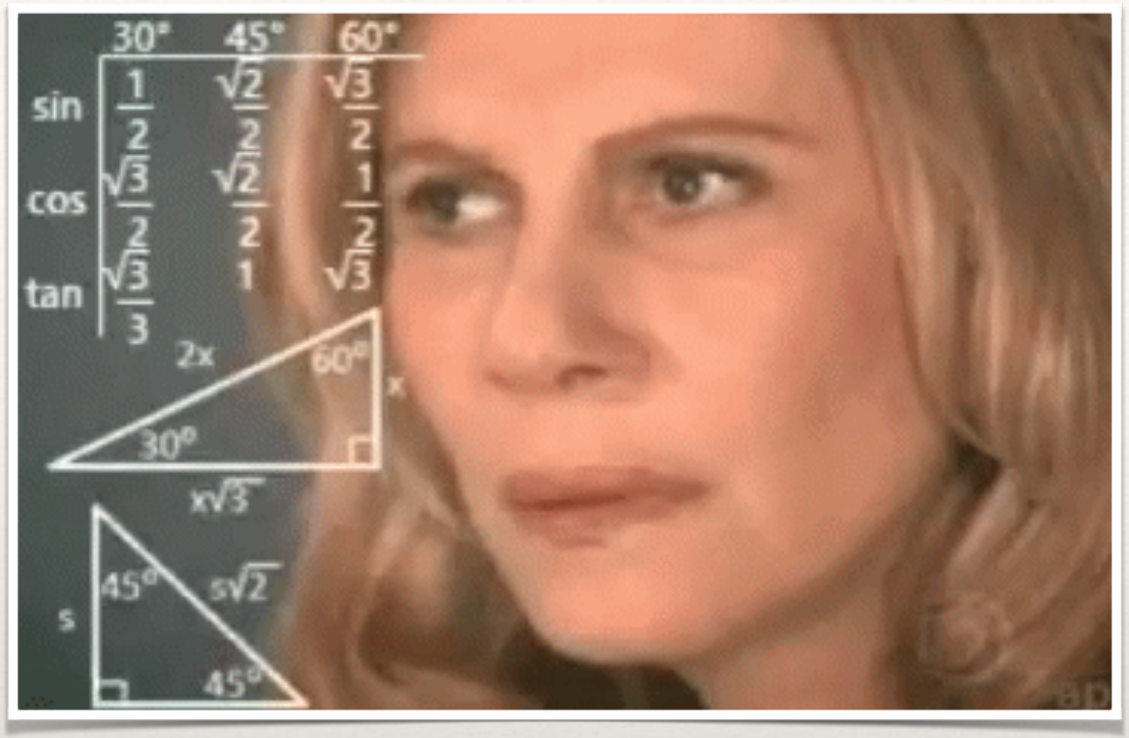
- ***Internet of Things*** as killer-app (scenario) confirmed?
  - flexibility –> re-configuration of device-device links, run-time composition of functionalities, adaptable event-condition-action rules, etc.
  - space-awareness –> relocation of devices, mobile computing, context sensitive computations, network-awarenesse, geospatial data, etc.
- Experience matured in service composition is a plus
  - i.e. the Web of Things vision seeks for it, based on web services
  - i.e. micro-service RESTful architectures for distributed computing flourishing

Conclusion: facts

- Relevance of coordination steadily increasing
  - confirmed by citations/year and downloads/year trends
- Few tech papers, downward trend, but good impact
  - ~12% tech papers (decreasing), most cited/downloaded ~40%
- Few actively developed software, more still available but discontinued
- Linda and IWIM reference coordination models
- Programmability and mobility most pervasive features

Conclusion: opinions

- COORDINATION plays key role in tech development
  - confirmed by surveys considering other venues [Papadopoulos, 2001] [Rossi et al, 2001]
- Software is relevant scientifically, as the tool enabling scientific discovery in computer science
  - as the telescope did for Galileo regarding observation of stars and planets
  - i.e. may provide feedback for refinement / conception of coordination models
- ***Time is ripe for pushing forward***
  - IoT at "peak of inflated expectations", "plateau of productivity" in 2–5 years [Gartner's hype cycle, 2017]



Questions?

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References

- [LINC at Bag-Era, 2016] http://bag-era.fr/index_en.html#about
- [Gelernter, 1985] “Generative communication in Linda”
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- [Omicini, 2007] “Formal ReSpecT in the A&A perspective”
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- [Papadopoulos, 2001] “Models and technologies for the coordination of Internet agents: A survey”
- [Rossi et al, 2001] “Tuple-based technologies for coordination”
- [Gartner’s hype cycle, 2017] https://www.gartner.com/smarterwithgartner/top-trends-in-the-gartner-hype-cycle-for-emerging-technologies-2017/

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