Indo- European co-operation in computing systems

Roadmap for 2020s

Dr. Sathya Rao

KYOS, Switzerland; sathya.rao@kyos.ch

EUINCOOP: 7th FP Support project

- Objectives
  - Develop cooperation in Computing Systems technologies between EU and India
  - Analyse state of the art technologies in both regions
  - Identify key players: Funding, organisations
  - Key Technologies addressed
  - Common interests for cooperation
  - Roadmap in the Horizon timeframe 2020

EUINCOOP
Cooperate Collaborate Connect

Partners

- FORTH: R&D Organization
  – Coordination
- KYOS: Service Company
- TOG: Industry Organization
  & Marketing Group
- IISc: Academic Organization
- CDAC: R&D Organization
- ITMSA: Networking Organization
  & National contact point for FP

Methodology

- Data collection from both regions in Computing Systems research: Region profiles
- Bringing together researchers and stakeholders from both regions
  - Experts advisory board, Workshops,
- Discussing and analyzing research agendas
  - Publishing and disseminating the results of the project
- Roadmap development
- Dissemination, feedback and awareness creation

Outcomes

- Cooperation of the Computing Systems community within current projects in Europe and India
  - Networking across the research communities from both regions
  - Map the decision makers, funding authorities, with emphasis on the Indian side
  - Develop Computing Systems Roadmap
- Joint R&D activities for mutual benefits
  - Instruments, Consortiums, exchange of experts, …
  - Key challenges
  - Funded projects
- Commercial exploitation through business models

Regional profile: Europe

- 500+ million population in 27 states of EU with less younger generation citizens
- Developed region with clearly defined structure of operation and Social security for the citizens
- Framework programme for R&D
- Strong industrial base: Services, but loosing their competitivity with emerging world.
- Economic crisis and unemployment
- Technology lead in HW and Industrial solutions
- Industrial and research Global players

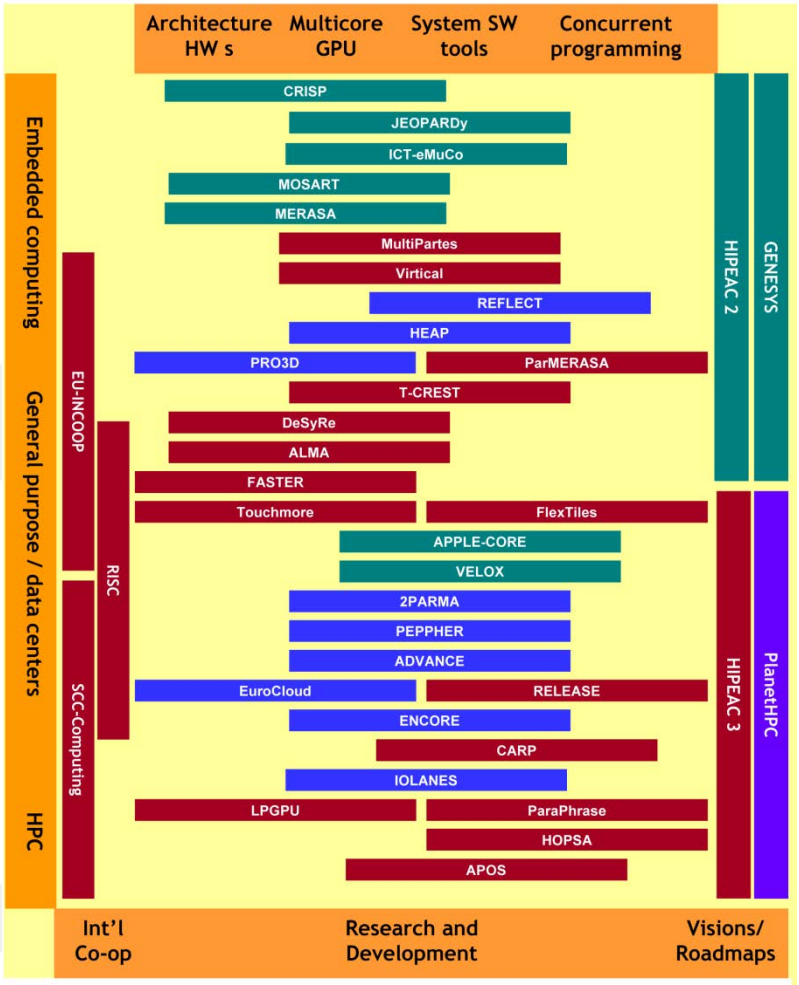
Computing system Challenges addressed in FP7

- operating systems, computer architecture, and their interaction
- System modelling and analysis
- distributed, parallel, and cloud systems
- networking, mobile, wireless, peer-to-peer, and sensor systems
- runtime systems and compiler/programming-languages support
- energy/power management
- file and storage systems
- virtualization
- embedded and realtime systems
- fault tolerance, reliability, and availability
- deployment, usage, and experience
- performance evaluation and workload characterization
- Reconfigurability

European FP7 activities

There are number of running projects addressing multiple issues of Computing Systems research covering;

- Architecture and Hardware
- Multicore and GPU
- System Software and Tools
- Concurrent Programming



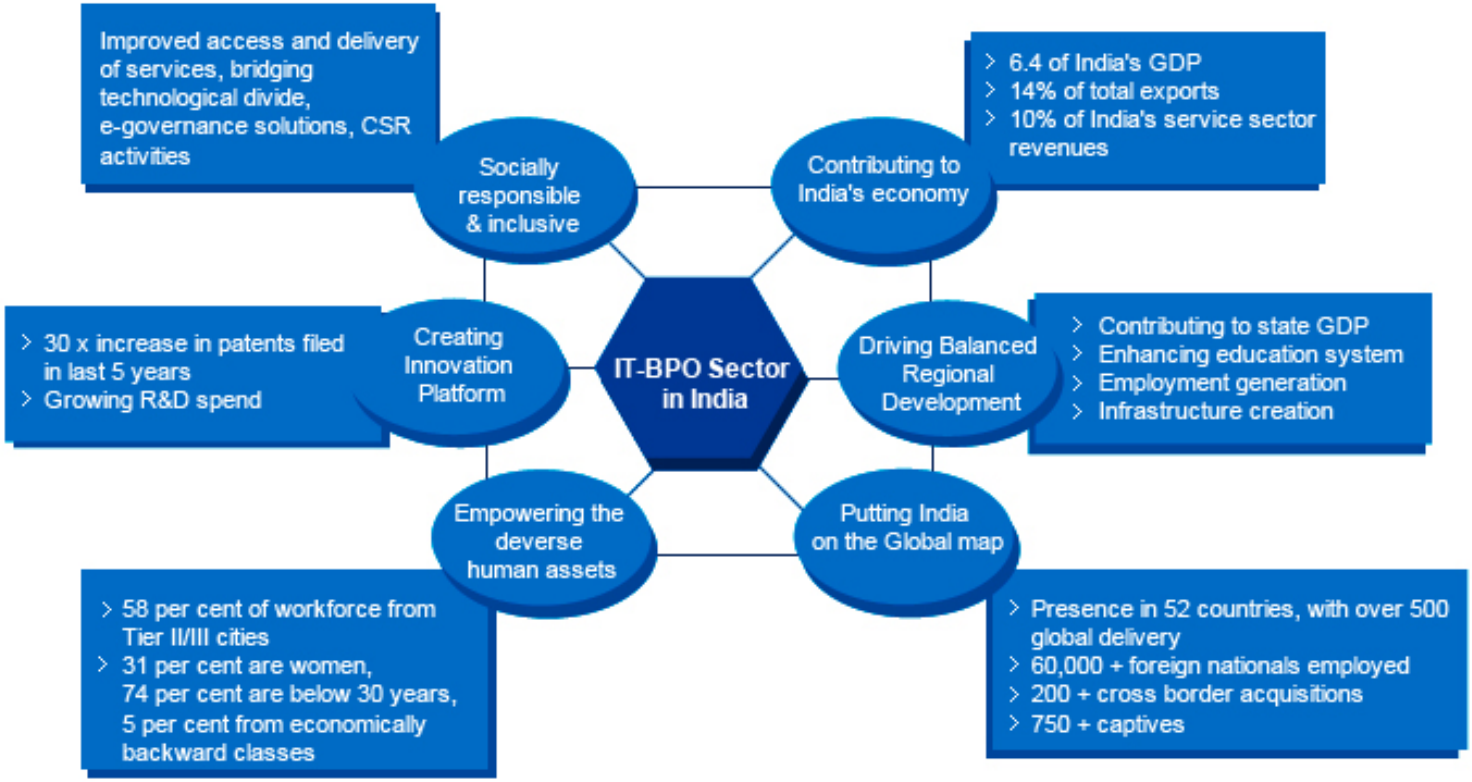
Visionary Projects

- European Technology platforms (ETPs)
  - ARTEMIS: ***A****dvanced* ***R****esearch &****T****echnology for* ***Em****bedded* ***I****ntelligence and* ***S****ystems*
    - www.artemis.eu
  - NESSI: *Networked European Software and Services Initiative*
    - www.nessi-europe.com
- Network of Excellence
  - HIPEAC
    - www.hipec.net
- Support Project
  - PlanetHIPC
    - www.planethpc.eu

Region profile: India

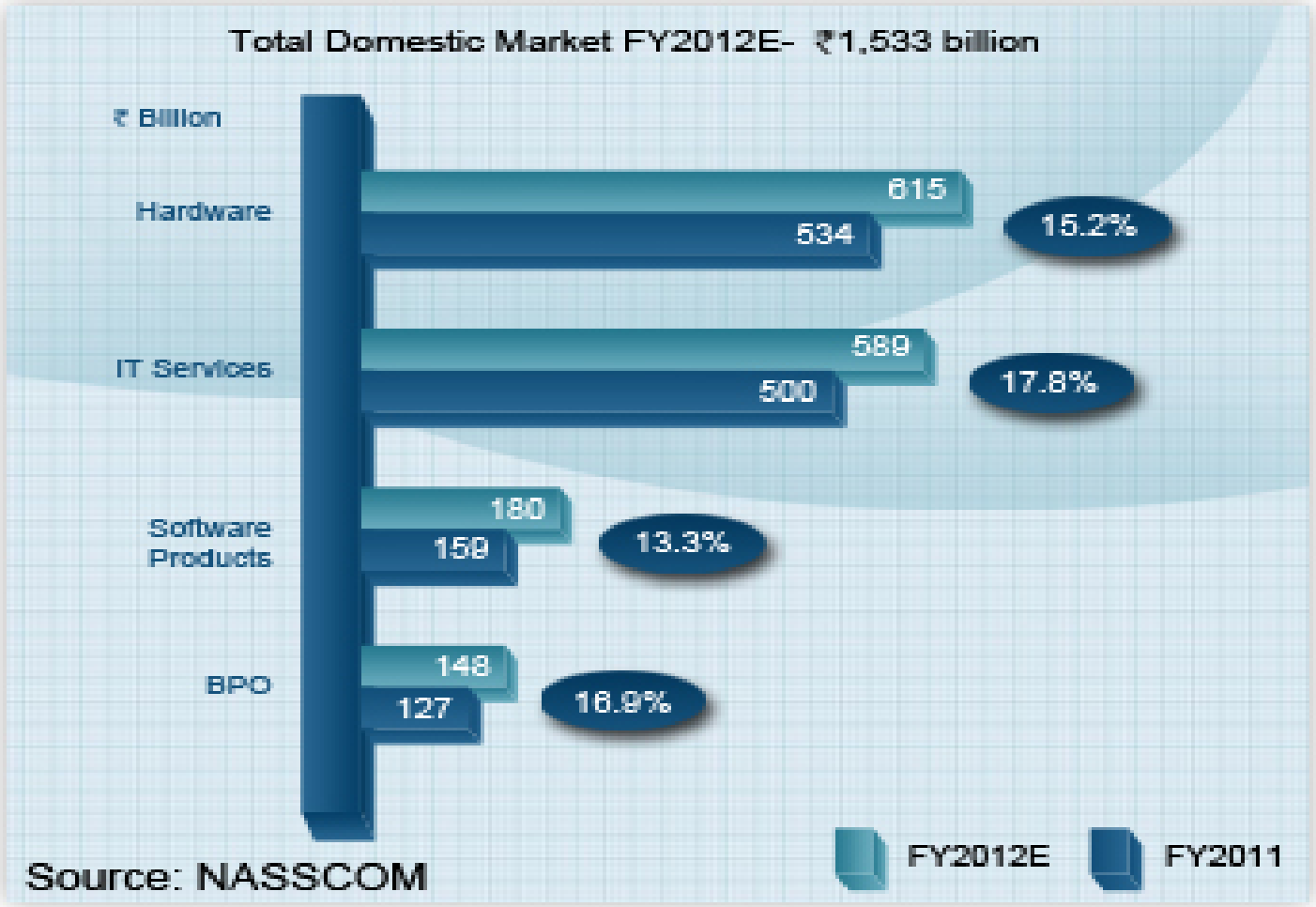
- Federal country with 28 states with strong democracy
- Liberalisation of markets in 1990s has changed the level of India's role from emerging market to Global player
- Population of 1.3 billion with average age of 35 years
- More than 10 million of IT professionals
- Economic growth between 6.5 -10% annually
- Software powerhouse for global players
- All major players have a base in India

IT-BPO sector in India



IT Services growth

Domestic market



Analysis activities from EUINCOOP

- Analysis of information on Indian Government and EU Priorities and Initiatives
- Analysis of ideas and best practices
- Open communication channels by conducting workshops
- Formulate a ‘Preliminary Research Roadmap’ enumerating the joint priorities of EU and India

Common Research priorities identified

- Multi core and Heterogeneity
- Parallelism and Energy Efficiency
- Performance analysis
- Data intensive HPC and Big Data
- Standardization and interoperability

Approach towards preliminary Roadmap

- **Analyzing Research Trends**
  - Research of published government documents, annual reports and other reliable sources.
  - Identifying common grounds and priorities between Europe and India.

- **Preliminary research roadmap**
  - Comparative analysis of information collected
  - Validation of the information with experts from the field
  - Discussion and consultation of project partners with experts
  - Analysis of work of European Technology platforms and roadmaps
  - Recommendations towards furthering collaboration by expert consultation and validation

Preparation of Back ground report

Objective	Methodology
To understand the rationale of funding mechanisms and the approaches.	Analysis of various computing systems initiatives in India
To identify the key actors and their research interests and priorities	Research on the projects executed by several research organizations, academic institutions and government organizations
To establish an expert committee to validate and guide the project activities	To choose experts from relevant areas in computing systems

Outcome of this activity:

- **A background report on the computing systems Research Scenarios**
- **Establishment of an expert committee 5 experts from India and 4 experts from Europe**

Approach adopted

- Analysis of the components of a research roadmap from the Indian funding perspective
  - Motivation
  - Desired advances in Technologies
  - Actions taken
- Understanding the needs and motivations of India and Europe
  - Technology
  - Individual
  - Business
  - Government
  - Society

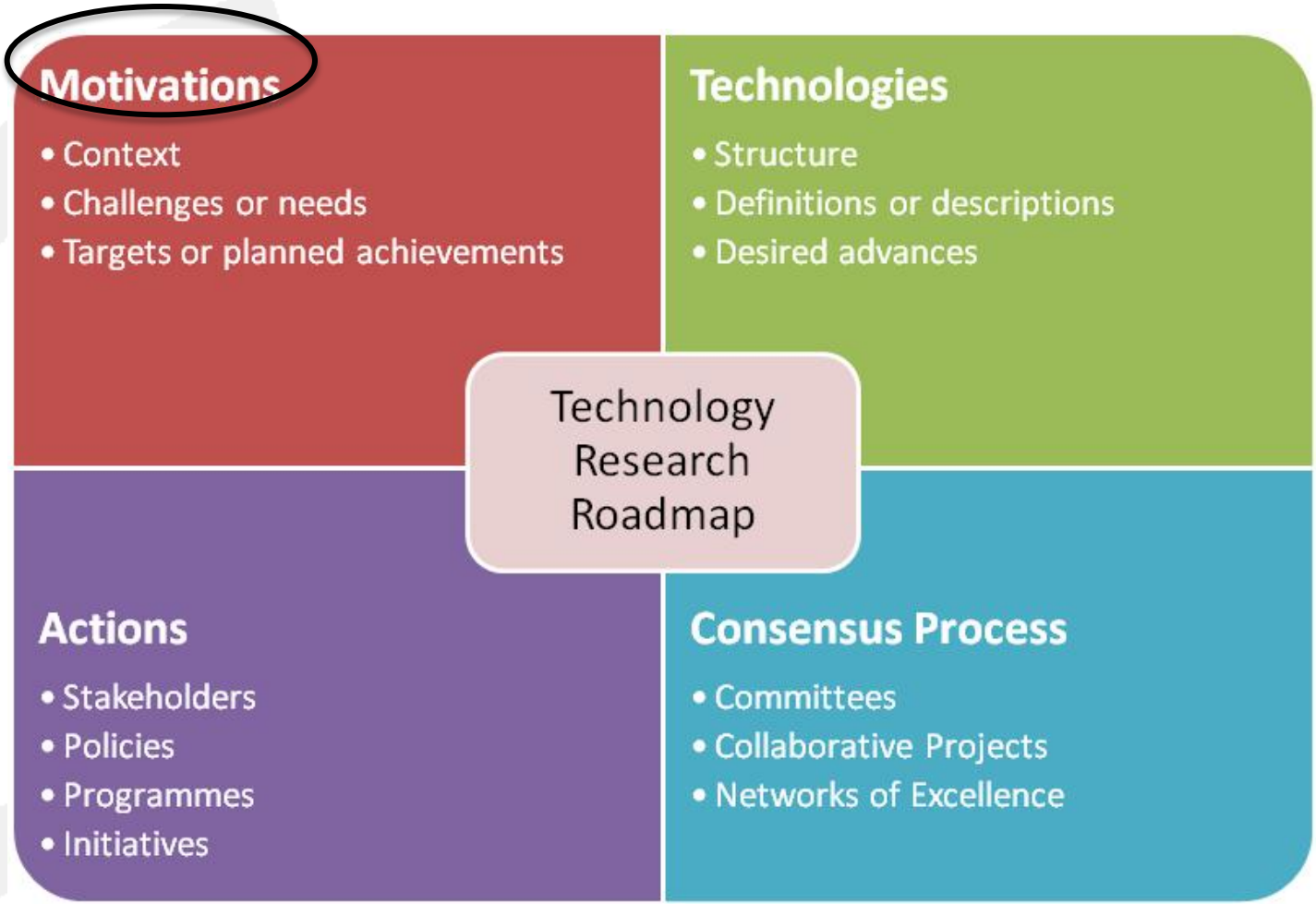
Roadmap Comparison

- India
  - Government funded research initiatives
  - Industry funded research initiatives
  - National priorities during the 11th and 12th 5 year plans (IT sector)
  - Strategic plan for the next 5 years (Department of IT)

- EU
  - HiPEAC – Network of Excellence
  - PlanetHPC – Support Action
  - ARTEMIS – European Technology Platform
  - NESSI - European Technology Platform

Analysis of the components of the research roadmap

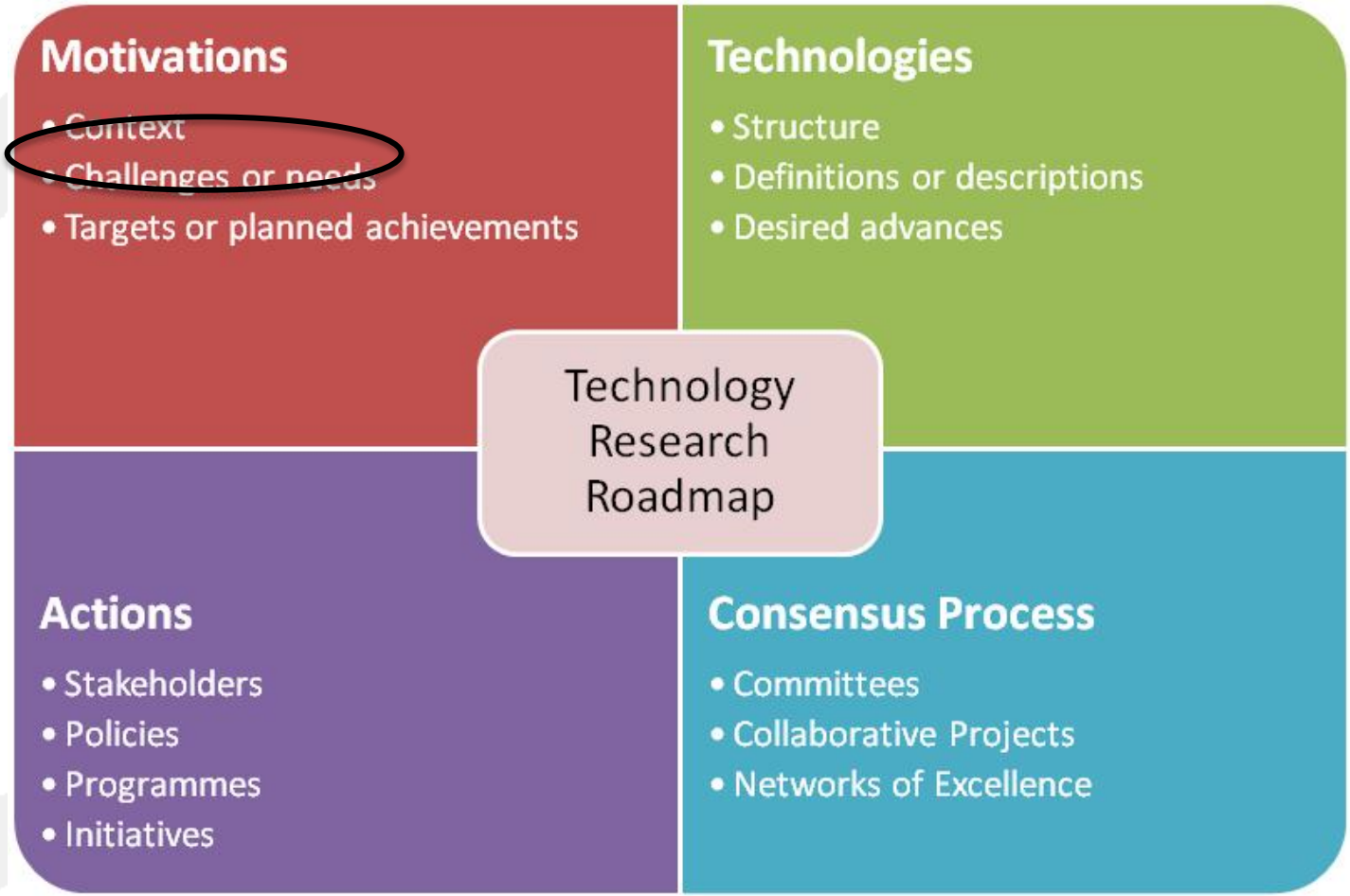
Research Roadmap Elements



Comparison: Motivational Statements

India	HiPEAC	PlanetHPC	ARTEMIS	NESSI
• Contribute to overall socio-economic growth of the country • Promote R&D for development, commercialisation and manufacturing of products, packages and services • Widen the R&D base in the country, and expand R&D infrastructure • Innovation promotion and development of entrepreneurs	• Complexity arising from multicore • Power efficiency for platforms • Increasing data volumes • Heterogeneous systems	• Scalability to support many-core platforms • Accessibility of HPC technology for business • Usability of HPC for building applications • Migratability of HPC to new platforms	• Affordable Healthcare and Wellbeing • Green, safe, and supportive transportation • Smart buildings and communities of the future	• Sustainable economic and social benefits • Lack of interoperability • Fragmented digital markets • Rising cybercrime and risk of low trust

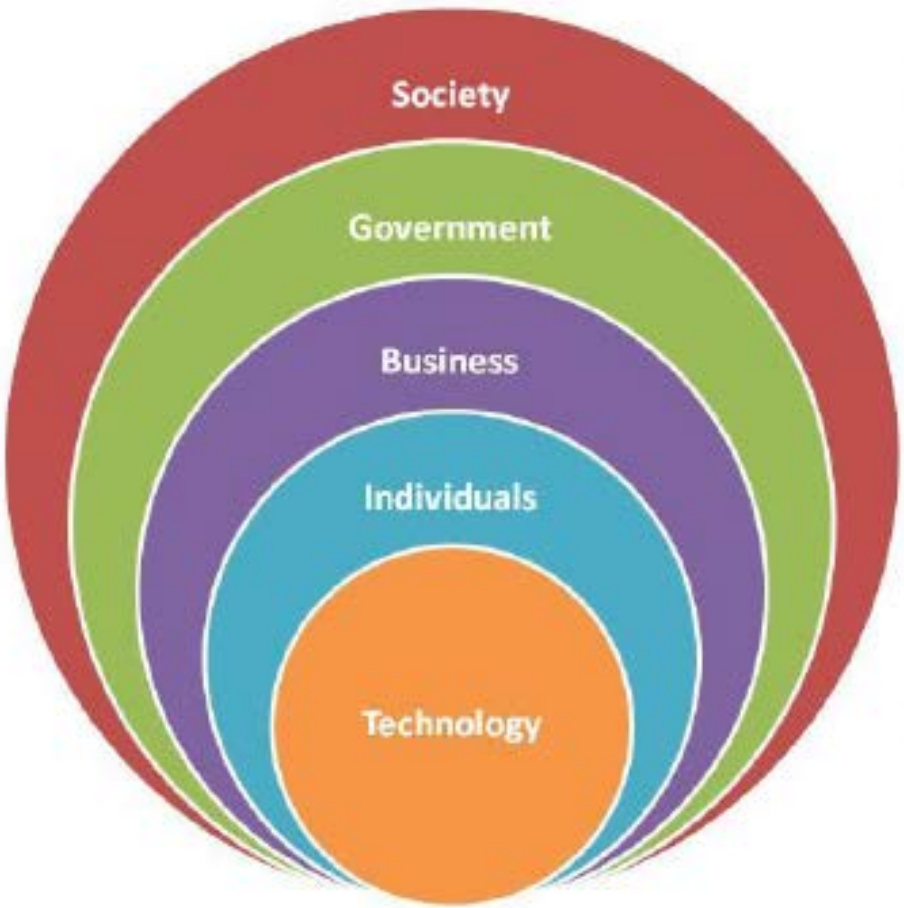
Research Roadmap Elements



Comparison: Challenges Identified

India	HiPEAC	PlanetHPC	ARTEMIS	NESSI
• Strengthen innovation in product design, development of value added products • Strengthen research Linkages between academics-industry • Capacity Building in research institutes • Infrastructure creation amongst research institutes • Support for Centres of Excellence • Support for Entrepreneurship • Encourage "Made in India" Goods	• Efficiency • Complexity • Dependability	• Scalability • Availability to business • Ease of use • Openness • Power efficiency	• Sustainability • Design efficiency • Ease of use • High added value • Time to market • Modularity • Safety/security • Robustness • Competitiveness • Innovation • Cost reduction • Interoperability	• Interoperability of services • Global accessibility and pervasiveness of services • Securing software and services and making them trustworthy • Fast business cycles and increasing productivity by software and services

Understanding the needs and motivations of India and Europe



ARTEMIS: Societal needs

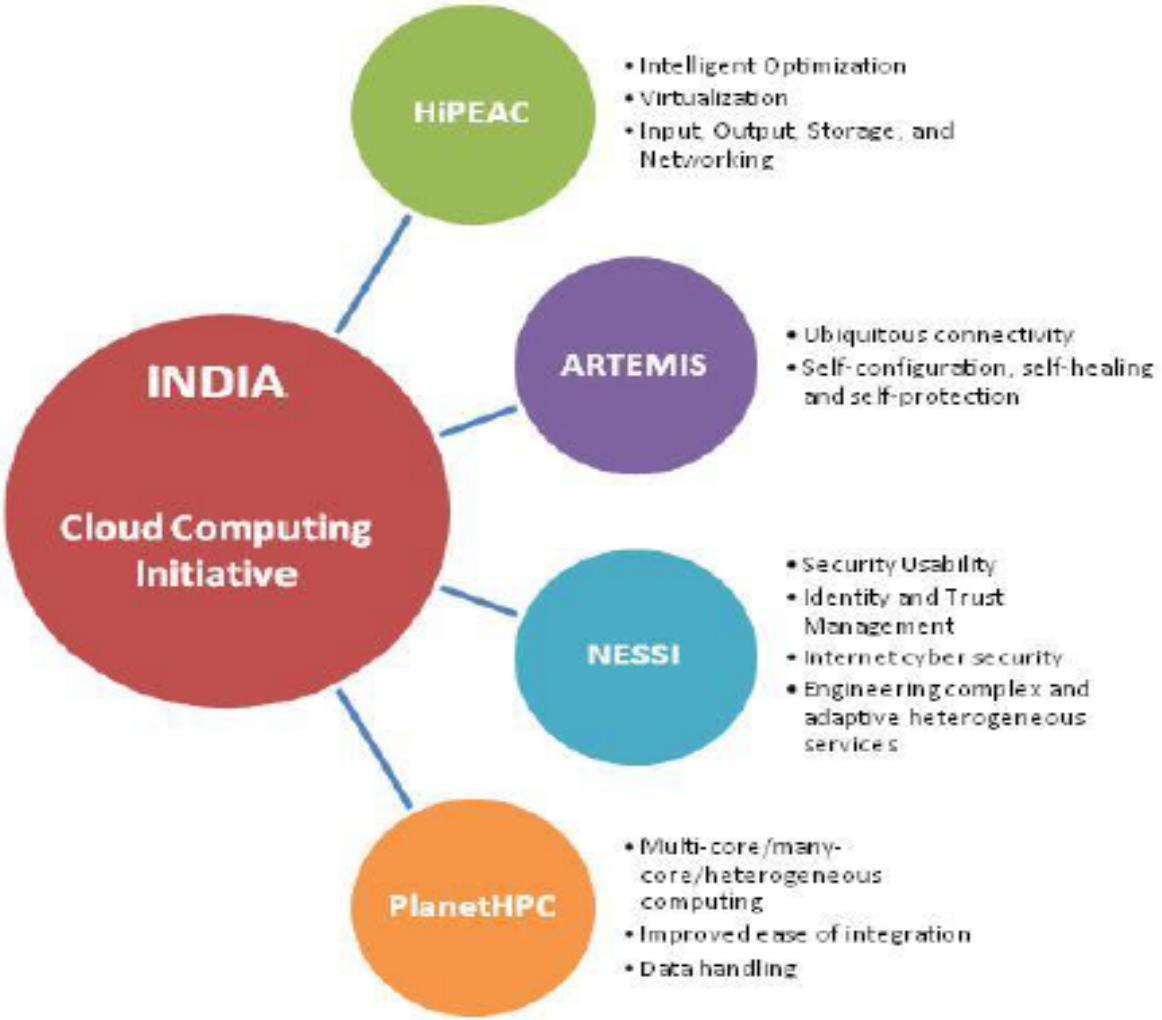
NESSI : Societal challenges

India : Governmental challenges

PHPC : Business IT needs

HiPEAC : Technology challenges

Mapped Indian Technology initiatives with that of EU



Organization of Workshop/Roundtable discussion

Objective	Methodology
To chalk out a roadmap for future synergies	• Organize Workshop • Invited speakers from Academia and Industry
To discuss concrete actions for EU-Indian collaboration	• Deliberate on Gaps and Needs • Brainstorm and made Recommendations and Suggested Actions
Outcome : • Inputs on what would be the future research trends going by the current needs • Recommendations to come together for strengthening collaborative research • Submission of the recommendations to Government of India and EU	

Preliminary research roadmap

Objective	Methodology
Identify high priority research topics common to India and EU	• Collation of the expert views and opinion • Analysis of Indian research roadmaps and framework documents • Analysis of EU roadmaps
Deliberate on the research challenges and steps to be taken to fulfill those needs	• The inputs from experts to be transcribed and collated
Outcomes: A report on the priority research topics and application domains and societal needs pursued by Indian scientific community Comparison of industry and research priorities and interests of Europe: A ready reckoner on the research priorities for the two regions	

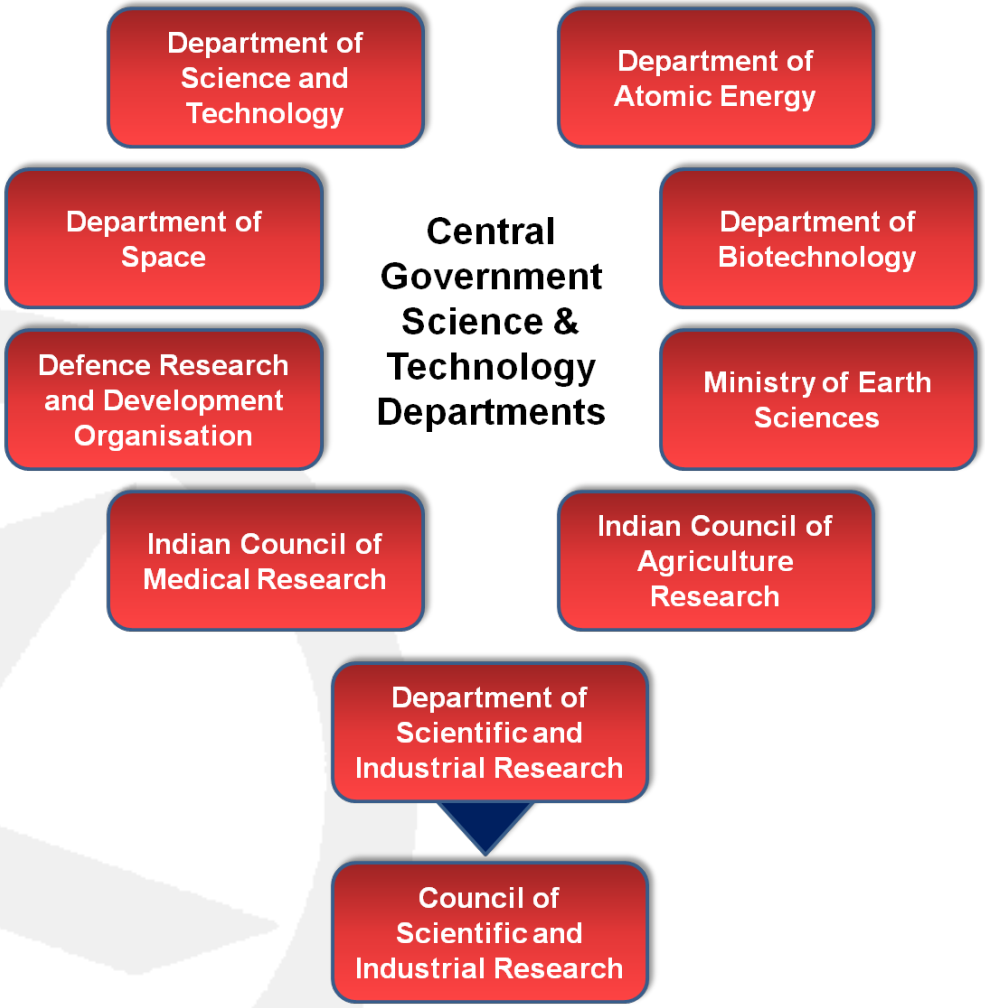
Key Actors identification in two regions

- Identification of Indian and European organizations within the broad computing systems spectrum
  - Focused on Indian organisations as European participation in research is easily accessible
- Analysis of EU and Indian organisation competences and interests in computing systems topics
  - Types of projects funded in India
  - Research topics common to both EU and India funded projects and degree
  - Topics that are unique in each region
- Online forum for EU and Indian organisations to have a voice in prioritisation of topics for computing systems research
  - Currently using Facebook / Twitter
  - Launching Forum in February 2013

Indian CS funding sources

Characterisation

- Governance
- Level of funding
- Funding mechanism and procedures
- Ongoing and recent CS related projects



Key actors in India funded projects

- Primarily Universities and Institutes are government funded for CS research
  - Centre for Development of Advanced Computing* (C-DAC)
  - Indian Institute of Science (IISc)
  - Indian Institutes of Technologies* (IIT)
  - Grid Applications Research Laboratory (GARL)
  - Dhirubhai Ambani Institute of Information and Communication Technology (DA-IICT)
  - Center for Soft Computing Research
  - NITT Tiruchirappalli
- Information provided for each Indian actor
  - Description
  - Listing of projects
  - Links to projects web pages

Analysis of EU and India funded projects

- Analysis of EU funded project topics
  - Multicore
  - Virtualisation
  - Parallelisation
  - Platform and Hardware
  - Performance Analysis
  - Predictability
  - Reconfigurability
  - Composability

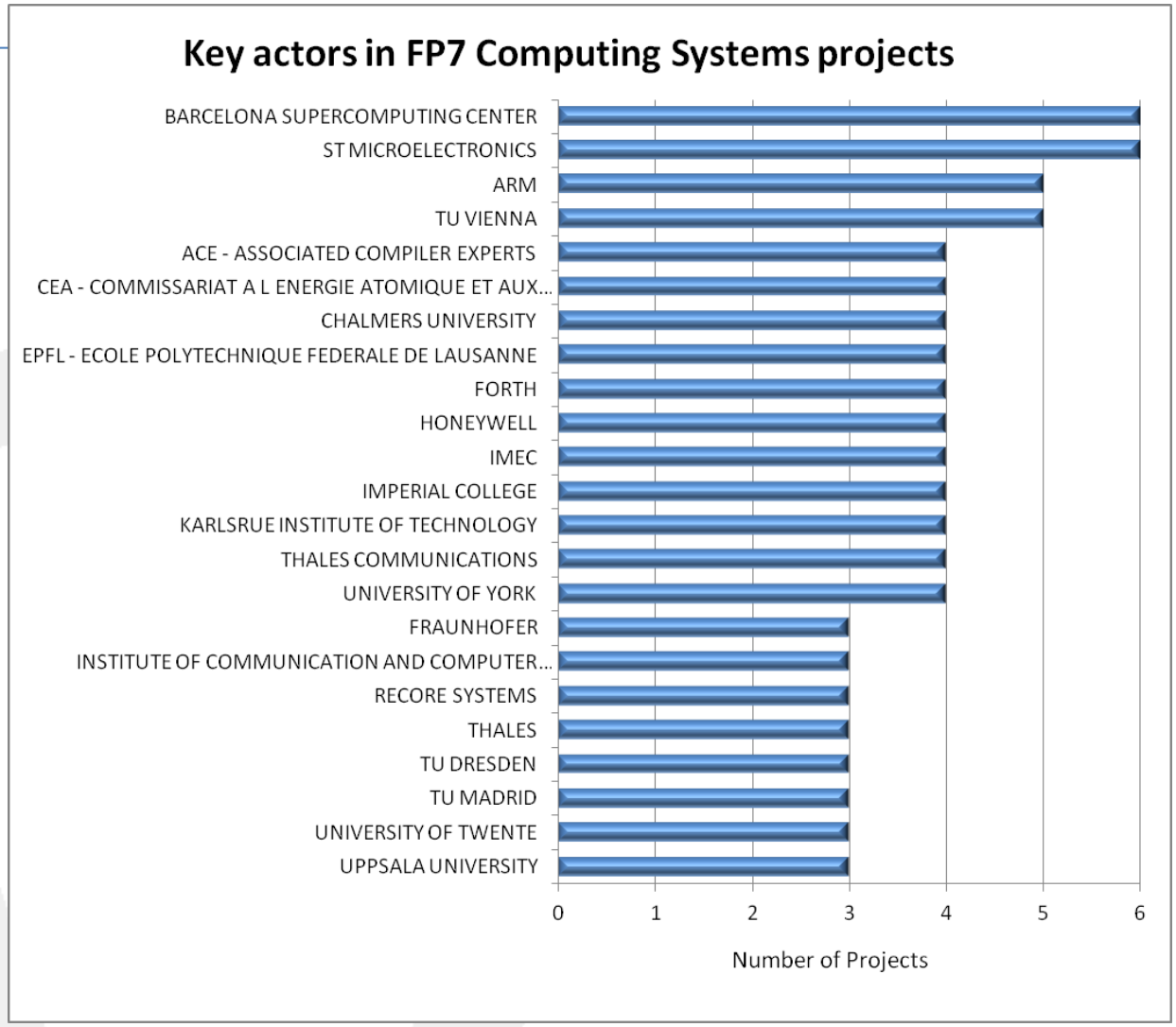
- Prevalent topics amongst India funded projects
  - Multicore
  - Parallelisation
  - Performance Analysis

- Identified 11 EU funded projects related to India projects
  - APOS-EU
  - PARAPHRASE
  - ParMERASA
  - RELEASE
  - TOUCHMORE
  - ENCOREHEAP
  - APPLE-CORE
  - JEOPARD
  - MOSART
  - VELOX

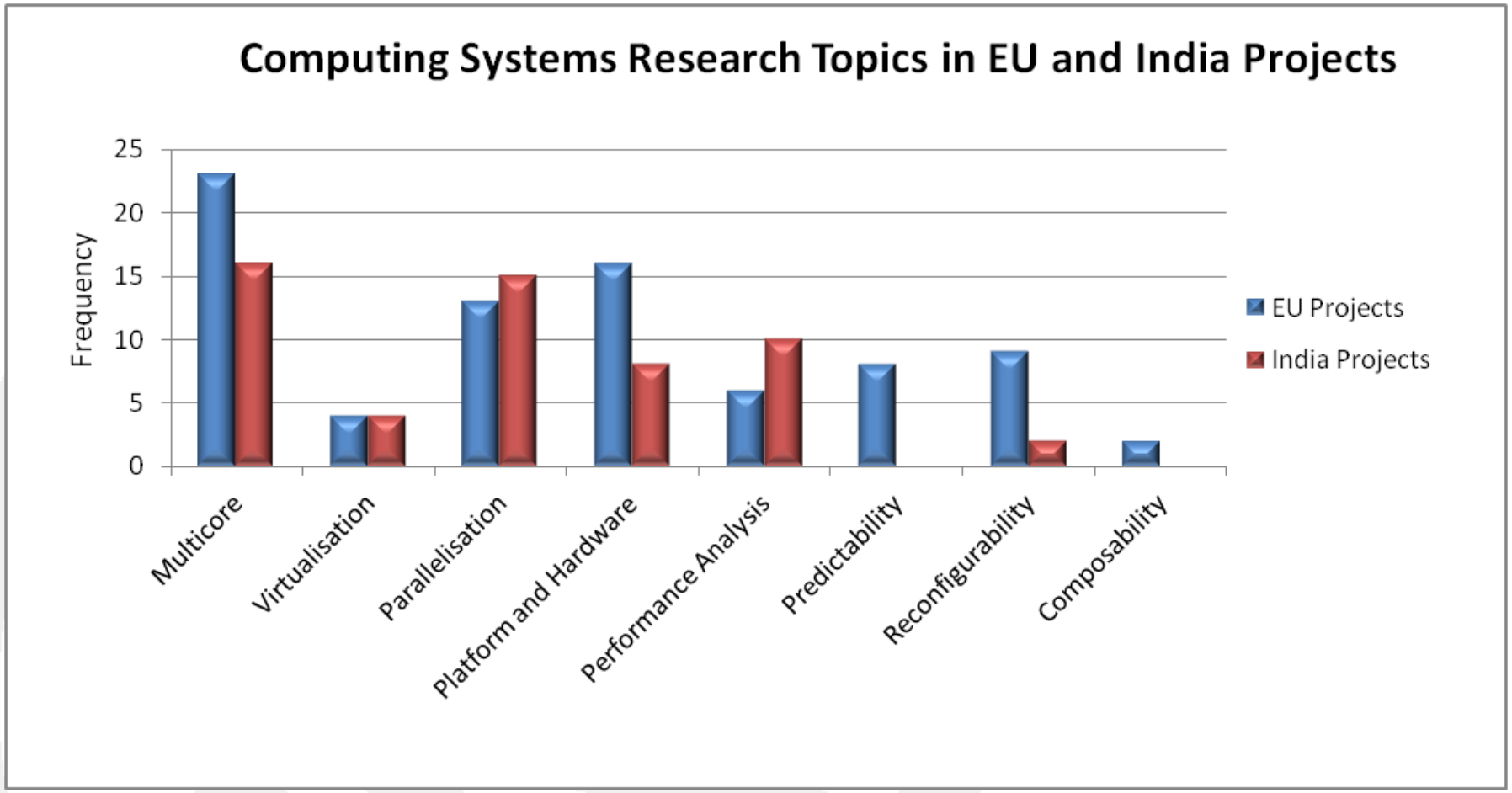
Provided project descriptions, contacts, partner lists and website links

EU actors involved in CS projects

- Enables Indian organisations to identify those most active in EU funded CS research
- Cordis link provided for searching contact information and related projects



India / EU research topics analysis



Predominately Indian topics: data mgmt, analytical engines, sensors / sensor nets, merging grid + ubiquitous, neural networks, spoken language

Preliminary Research Roadmap

- Common Research priorities identified
  - Multi core and Heterogeneity
  - Parallelism and Energy Efficiency
  - Performance analysis
  - Data intensive HPC and Big Data
  - Standardization and interoperability

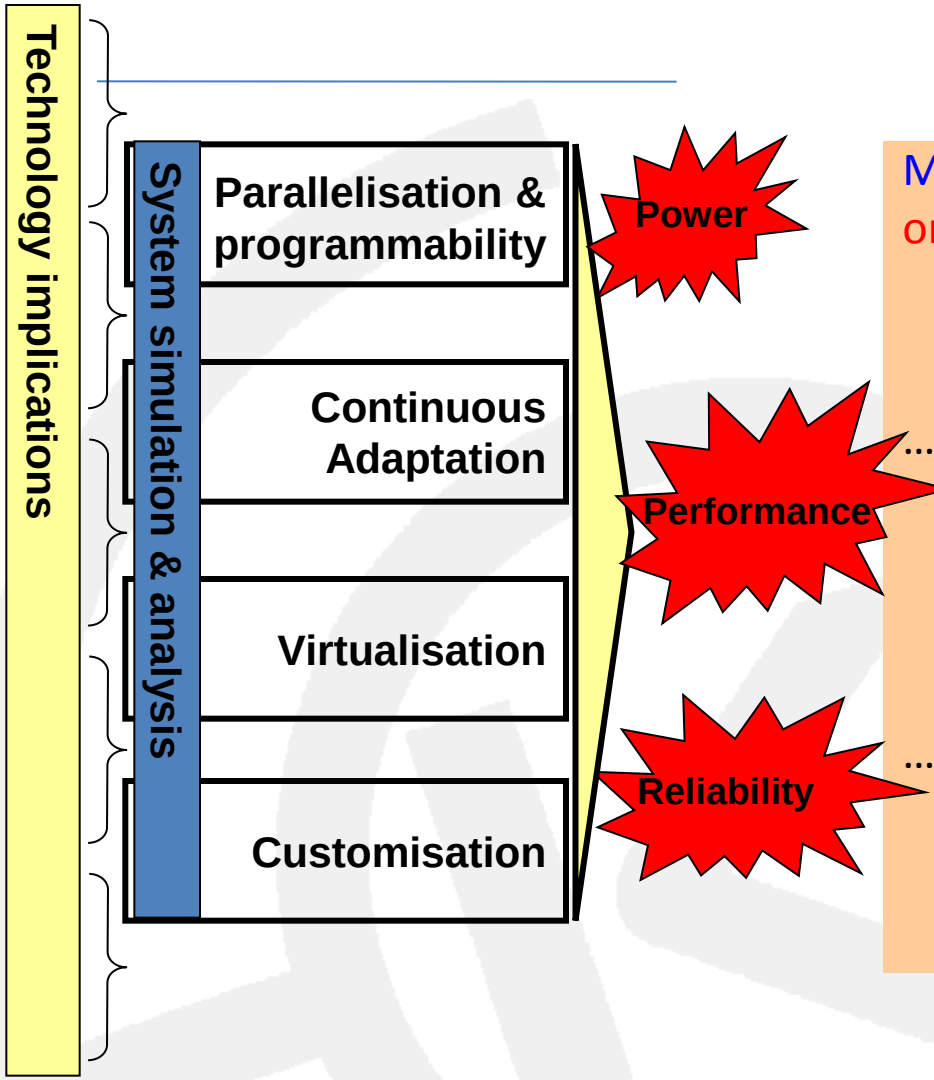
Ubiquity in computing and Communication

Meeting the contraints:

- VLSI density
- Frequency
- Parallelisation
- Energy consumption
- Number of cores
- Task sharing
- Performance

Challenges lie both in Hardware and Software development with International collaboration

Challenge in Computing: System of Systems



Multicore and/or reconfigurable on-chip computing systems must offer …

- *More **performance***
- *More **power-efficiency***
- *More **reliability***

… through breakthroughs in …

- ***Parallelisation & Programmability***
- ***Continuous Adaptation***
- ***Customisation***
- ***Virtualisation***
- ***System simulation and analysis***

… without forgetting …

- ***technology implications***
  e.g. ***3D stacking***

Technology Trends

- Parallel computing
- Cloud computing
- High performance computing
- Adaptive application deployment
- Programming complexity
- Merging computing domains
- Cross-layer optimisation

Parallelisation & Programmability

- Automatic parallelisation, new high-level parallel programming languages and/or extensions to existing languages taking into consideration that user uptake is a crucial issue.
- Projects on programmability & parallelism of multi-core and/or reconfigurable architectures should adopt a holistic approach addressing issues related to the underlying hardware and to the system software.
- Research areas include
  - beyond static auto-parallelisation by exploiting dynamic (run-time) information;
  - new support environments including testing, verification and debugging, program & performance monitoring and analysis;
  - specific hardware support for parallel programming models.
- High impact on performance and energy to be managed by Software

Methodologies, techniques and tools

- **Continuous Adaptation:** Multicore and/or reconfigurable systems that continuously adapt to a constantly changing environment by going beyond the strict separation between compiler, runtime and hardware.

- **Virtualisation** technologies that ensure portability, flexibility, optimised use of resources and overcome legacy issues for multicore and/or reconfigurable systems. This includes hardware/software interfaces for efficient virtualisation as well as machine abstractions and performance models for virtualised homogeneous or heterogeneous systems applicable to cloud computing.

- **Customisation:** Rapid extension and/or configuration of existing systems, architectural templates and tool-chains to optimally address specific application needs and performance/Watt envelopes.

System simulation and analysis

- **System simulation and analysis:** Advanced simulation and analysis of complex multicore systems to drastically improve the simulation speed of new complex, homogeneous or heterogeneous, multi-core systems
- Date deluge system management and software to manage concurrency in exascale HPC systems
- Need of tight cooperation between hardware and software technologies, including the operating, runtime systems and applications, is necessary to address the energy challenge in new generation HPC systems

New challanges

- Merging computing domains
  - migration towards a computing continuum
    - Same key technologies and players acting across all computing segments: embedded, mobile, desktops, servers, data centres, clouds
    - application usage of computing resources cutting across the computing spectrum such as embedded systems utilising HPC functionalities and HPC systems used in time- and safety-critical applications

New challenges

- Embedded computing
  - single core controllers to multi to manycore systems; from local buses to switched and open embedded system networks; from single application contexts to application integration and from individually maintained systems to autonomous, self-X systems
- Power Consumption and related funtionalities
  - increasing influence on both hardware and software architecture, while timing, safety, reliability, availability and security are of increasing importance at the core of critical systems
- Low cost clusters
  - powered by multicore CPUs and GPUs takes HPC capabilities to a much wider audience

European Horizon 2020

- 7 year major programme involving multi-billion € funding
  - Solutions for Societal challenges: Europe's productivity and innovation capacity and ensuring Europe has an advanced, sustainable and competitive economy, global leadership in high-tech application sectors
  - 'Leadership in enabling and industrial technologies' following a technology-driven approach to develop enabling technologies that can be used in multiple areas, industries and services to meet Societal challenges
  - Key Enabling Technologies (KETs): micro- and nanoelectronics, photonics, nanotechnology, biotechnology, advanced materials and advanced manufacturing systems

- Business oriented vision
  - Strong private sector involvement
    - public private partnerships, involvement of SMEs a must
    - market needs and the requirements of the societal challenges

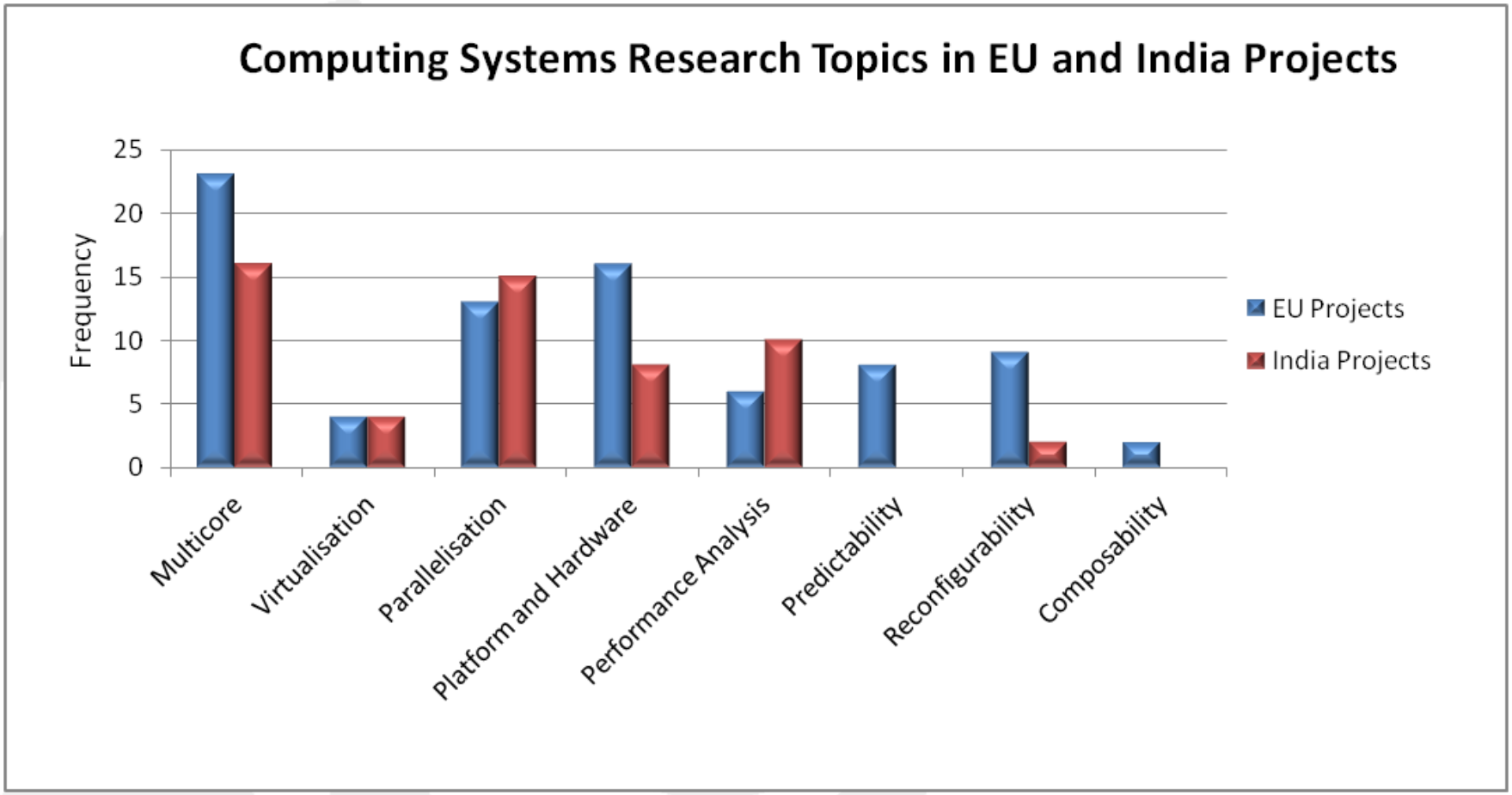
Indian Vision and challenges

- Consortium funding systems.
- Possibilities of funding international S&T cooperation
- Participation in global research consortia.
- Research in national priority areas such as Water, Energy, affordable Health Care etc,
- Stronger focus on enlarging the role of private sector into Research and Development
- Establishment of Technology Platforms
- Soceital applications and next generation computing

Technology areas for cooperation

- Multicore
- Virtualisation
- Parallelisation
- Platform and Hardware
- Performance Analysis
- Predictability
- Reconfigurability
- Composability

EURO-INDIA Co-operation opportunities



Research Collaboration: EU vs India

		Heterogeneous computing systems	Locality and communications management	Software for heterogeneous multi-cores	Cross-component/cross-layer optimization	Next -generation processing cores	Architectures for the Data Deluge	Reliable systems for Ubiquitous Computing
Parallelism and Programming Models								
9.1.1.	Locality Management	x	x	x	x	x	x	x
9.1.2.	Optimizations programmer hints, tuning	x	x	x	x			x
9.1.3.	Runtime Systems and Adaptivity	x	x	x	x		x	x
Architecture								
9.2.1.	Processors, Accelerators, Heterogeneity	x	x			x		x
9.2.2.	Memory Architectures	x	x		x	x	x	
9.2.3.	Interconnection Architectures	x	x		x	x	x	
9.2.4.	Reconfigurability	x	x		x	x		
Compilers								
9.3.1.	Automatic Parallelization		x	x		x		
9.3.2.	Adaptive Compilation			x			x	x
9.3.3.	Intelligent Optimization			x	x	x		x
Systems Software and Tools								
9.4.1.	Virtualization	x		x	x		x	x
9.4.2.	Input, Output, Storage, and Networking		x		x		x	
9.4.3.	Simulation and Design Automation Tools	x			x	x		
9.4.4.	Deterministic Performance Tools	x	x	x	x	x	x	x

Opportunities on different challenges

Disruption	European Opportunity	Indian Opportunity
Energy efficiency is becoming as important as performance where components increasingly come from the low power mobile world rather than the more power hungry desktop world. Tablets and smartphones are driving new innovation and markets.	Europe has significant strengths in low power, low cost processing for battery powered devices.	**India has strong expertise in system software to develop new features for energy awareness and to exploit these at application design and deployment.**
The data deluge and the end of the increase in processor clock speeds for powering hardware innovation are leading to a new generation of computing systems, which are increasingly parallel and heterogeneous.	Europe has the skills in parallel processing and the ability and expertise in both embedded and supercomputing technologies which when combined provide opportunities for capitalising on this technology revolution.	**India has substantial skills in addressing large data challenges in several scientific disciplines and years of experience in parallel processing that can be applied to scale applications to exploit new heterogeneous architectures.**
There is a trend towards a computing continuum with the same key technologies and players acting across all computing segments, and application usage cutting across current computing disciplines.	Europe can expand from its strengths in embedded, mobile and high performance software.	**Indian can extend from its strengths in HPC computing to further develop world class expertise in embedded and mobile software.**
A new era of enterprise software given the emergence of ground breaking technologies such as cloud computing, multi- and manycore processors, and main memory database technology. In addition, the Internet of things has become reality generating massive data volumes.	Europe has world leading capabilities in enterprise software and expertise in developing system software that exploit new platform architectures especially in areas related to mission or safety-critical domains.	**India has world leading capabilities in enterprise software and expertise in exploiting new technologies for developing enterprise applications and adapting technologies to many different industrial domains.**
High bandwidth networks based on the widespread deployment of broadband – fixed and mobile – enables promising new business models leveraging the cloud computing paradigm.	This opens access to advanced computing resources and application services to European actors to who these were out of range in the past, in particular SMEs.	**This creates new opportunities for India's large base of software suppliers to access and exploit new HPC technologies for innovative applications and services.**
The cost of developing new hardware approaches in silicon is dropping due to the use of FPGAs for prototyping and novel ASIC manufacturing methodologies.	**Europe has world leading expertise in integrated circuit design through its embedded community.**	**India has world leading expertise in developing applications that exploit new hardware designs and lower cost platforms.**

Common Euro-India Research Challenges

1. Software for emerging platforms
2. Software for internet based systems
3. Software for Big Data
4. System software for enterprise
5. Network embedded system interoperability
6. Software for social computing
7. HPC Technology Platform

Software for emerging platforms Challenges

- Hardware platforms are increasingly becoming heterogeneous
  - Need of automating software development for highly parallel and heterogeneous environments
  - challenges for European and Indian software developers in addressing high levels of parallelism, new memory, storage and connectivity configurations
  - ease of programmability, portability and exploiting performance of new multi- and manycore platforms
  - technology innovations to migrate and extend existing software to exploit parallelism

Possible approach

- Use of algorithms as an abstraction layer, combined with automated parallelisation based on that abstraction
- Model-based engineering technologies that better address properties related to parallelisation during design combined with new transformation technologies to automate exploitation of parallelisation at deployment
- Increased run-time intelligence to dynamically adapt software to better exploit parallelism of the platform
- New languages that aid in the expression of parallelism and that provide better mapping or automation of algorithm design

S oftware for internet based systems Challenges

- Future Internet and services are large scale software systems that are distributed across wide geographic areas, and are highly complex
- Need of new computing system to guarantee security, quality of service, resilience and resource optimisation across service platforms
- Technologies for virtualization, management of manycore platforms, development tools, and web standards are expected to be core technologies that will lower the capital expenditure

Possible solutions

- modelling the architecture and behaviours of large scale distributed software systems
- dynamic resource allocation in manycore embedded and high performance systems with energy efficiency
- different types of cloud-like resource management infrastructures
- resource allocation techniques that are sufficiently lightweight to be applied during runtime
- scalable resource allocation techniques
- extensions to existing system software (OS, virtual machines, middleware) to support predictable runtime migration of tasks and virtual machines

Software for Big Data Challenges

- diversity of information to be analysed as data may come in a variety of forms from very structured (tables in relational systems, XLS, HTML, PDF) to semi-structured (XML, web services, RDF) to unstructured (sound, image, etc.)
- data may be distributed between a large numbers of devices, of which many may be mobile, with different systems and formats, different models and ontologies
- quality issues with imprecise data, inconsistencies, and incompleteness along with capturing not only the data but indicators or metadata enabling the assessment of the quality and reliability of data
- identifying and adapting to external trends and changes amongst data providers that might affect the precision or reliability of data mining and analysis

Possible Approach

- Data centric system software exploiting manycore parallel computing platforms
- Asynchronous computing and distributed data focused run-time environments
- Scalability of open data management platforms and support for new approaches to analysis and visualization
- Optimisation through balancing or delegating work using techniques such as moving algorithms to local data stores
- Improving interoperability of data, techniques, and methods across tasks and scenarios

System software for enterprise Challenges

- The driver of innovation with dynamic integration of business partners
- Delivery through cloud platforms
- Adaptation of software for the market needs
- SW through the simple composition of standard solutions from multiple providers
- New Business models: greater flexibility in adapting and tuning and have systems that are more responsive or adaptable to market opportunities.

Possible approach

- automating interoperability of systems between enterprises
- automating adaptation of systems to dynamically accommodate changes
- distributed systems technology addressing the complexities of interfacing, managing and exploiting data from manufacture products with embedded intelligence
- system software supporting real-time data analytics and new enterprise database technologies and related programming and design tools to support rapid adoption
- manycore programming methods and models that transform service oriented architectures

Network embedded system interoperability Challenges

- Reliance on embeded systems to improve the citizens life improvement through Apps
- Technologies for networking and interoperability across spectrum of devices
- Exploitation of ubiquitous network topology to access information from different application domains
- Smart environment with better services and productivitiy

Possible approaches

- operating systems and virtual environments that can be distributed and composed, and are able to support dynamic reconfiguration
- resource augmentation enabling devices to identify resources accessible across a network such as cloud computing, HPC, or simply other more intelligent devices and to exploit these to dynamically improve quality of service and energy usage
- connectivity schemes that support ubiquitous syntactic and semantic integration of heterogeneous sub-systems, under the constraints of minimum energy usage and limited bandwidth
- self-configuration, self-organisation, self-healing and self-protection of computational components to establish connectivity and services, using knowledge acquired from the environment
- monitoring techniques for object and event recognition making possible new control tasks in large-scale systems

Software for social computing Challenges

- notion of data, information and knowledge in the social context where the bulk of raw data and information comes from users
- crowd-sourcing and mechanism of collective intelligence
- New applications assembling web based services
- tools and interfaces to support the interaction with the masses of data
- Analysis of social behaviour and impacts

Possible approaches

- Data intensive distributed computing system software and middleware
- Semantic-based data integration and standardisation
- Software optimisations and acceleration for reasoning in a huge-scale distributed environment
- Technologies for discovery, surveillance and managing dynamic and mobile data
- collaborate in creating an open, possibly anonymised, shared data set for use in testing advances in system software and middleware

HPC Technology Platform Challenges

- continued exponential growth in performance in computational components is facing disruption due to the effect of Moore's Law coming to an end
- future HPC systems if built using current technologies will consume an unacceptably large amount of electrical power
- applications that are critical for biotechnology, mitigation of natural disasters and other societal supporting sciences are already difficult to scale to exploit higher petaflop systems and will need substantial re-engineering for exascale systems

Possible approaches:Technology platform

- problems to be addressed require multidisciplinary science and engineering inputs where knowledge from different disciplines is applied in new and innovative ways
- contributions are needed from a range of different types of stakeholders in defining the solutions from research institutes to industry
- shared vision and leadership will provide substantial economic benefits in terms of the resources needed for research and development
- many real world applications for HPC appear diverse, but the underlying computing systems challenges are shared amongst large classes of applications making it feasible to develop HPC technologies that are applicable to a wide range of industrial and societal applications

Additional approaches

- programming models, languages and methodologies for manycore HPC architectures and tools to automate applications and improve developer productivity
- technologies for energy-aware application and system modelling, compilation and run-time environments for building energy efficient HPC systems
- modelling and simulation techniques that scale to expected levels of parallelism in manycore based HPC platforms
- exploiting technologies from other computing domains for mobile, embedded, cloud, telecommunications and sensors to address HPC
- definition of a common access framework for the HPC infrastructures

International cooperation

- Computing systems are managed in terms of optimised Hardware and Software components
- Europe has an edge in Semiconductor technologies with number of Internatoinal companies such as STMicro electronics, Infineon, ARM,…
- Has number of research centers for collaborative work, though limited in Industry-Academia networks
- India is a software powerhouse to complement.
- Number of National research institutes and international companies are active in India

Recommendations

- Address technologies identified for defining joint research and development projects
- Involve partners with expertise from both regions
- Consider a pilot project as a good kick-off to define regional priorities and collaboration instruments
- Promote public private partnerships both in regionally funded and jointly defined projects
- Address IPR and technology exploitation issues, so that collaboration is more fruitful.

Thank you

12 bis avenue Rosemont
1208 Genève

Tel: +41 792153566

Sathya.rao@kyos.ch