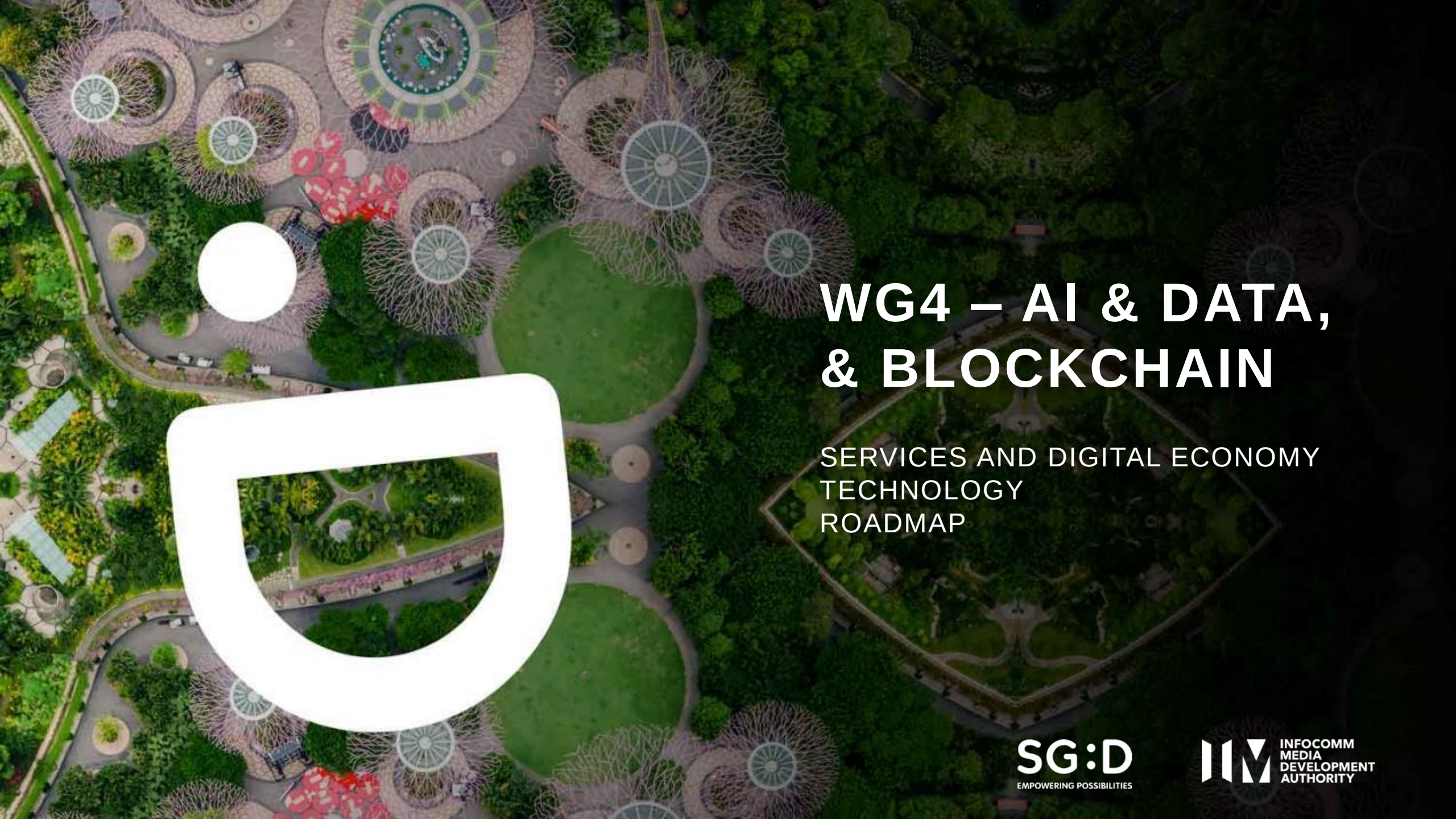


WG4 – AI & DATA, & BLOCKCHAIN

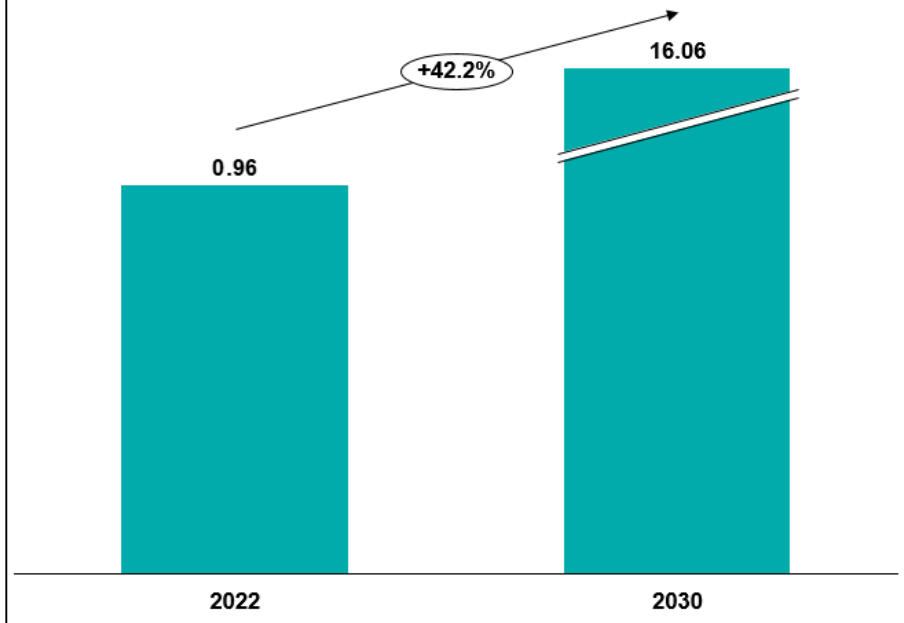
SERVICES AND DIGITAL ECONOMY
TECHNOLOGY
ROADMAP

SG:D
EMPOWERING POSSIBILITIES

INFOCOMM MEDIA DEVELOPMENT AUTHORITY

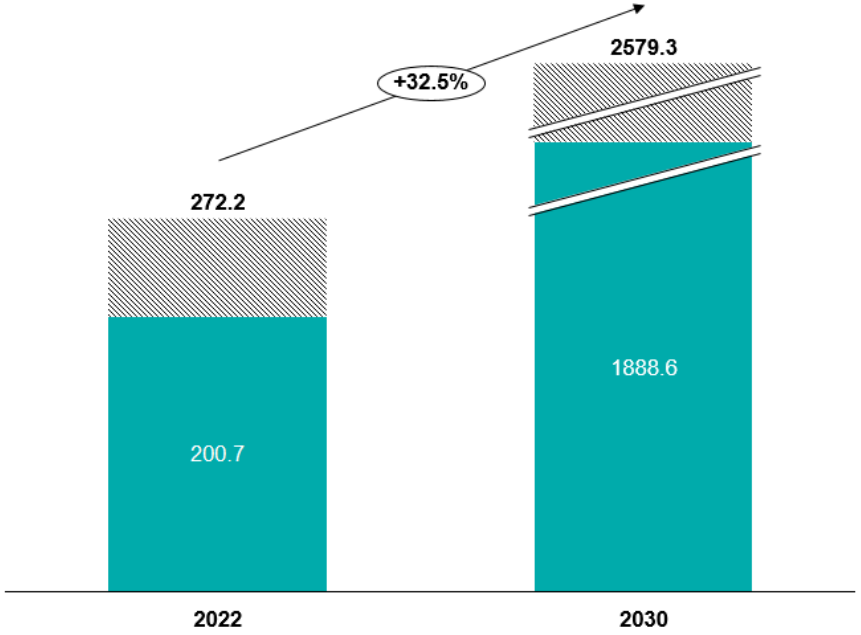
MARKET STUDY

Singapore AI Market Size[1]
USD Billion



Note: 1) Singapore's AI market size is triangulated based on data and insights from: IDC Worldwide Semiannual Cognitive Artificial Intelligence Systems Spending Guide; Gartner Forecast: Enterprise IT Spending by Vertical Industry Market, Worldwide, 2016-2022, 2Q18 Update; Gartner Forecast: Communications Service Provider Operational Technology, Worldwide by Country, 2016-2022; Gartner Broadband Access Systems by Region, 1998-2007; Gartner Consumer Communications Market Revenue 2007-2013; "Welcome to 2018, the year of AI", Microsoft Asia News, 3 January, 2018

Singapore Blockchain Market Size[1]
USD Million



Note: 1) Singapore's Blockchain market size is triangulated based on data and insights from: IDC Worldwide Semiannual Blockchain Spending Guide; Gartner Forecast: Enterprise IT Spending by Vertical Industry Market, Worldwide, 2016-2022, 2Q18 Update; Gartner Forecast: Communications Service Provider Operational Technology, Worldwide by Country, 2016-2022; Gartner Broadband Access Systems by Region, 1998-2007; Gartner Consumer Communications Market Revenue 2007-2013; D&B Hoovers;

SG:D EMPOWERING POSSIBILITIES

INFOCOMM MEDIA DEVELOPMENT AUTHORITY

DEFINITION OF AI

COMMON INDUSTRY UNDERSTANDING OF AI

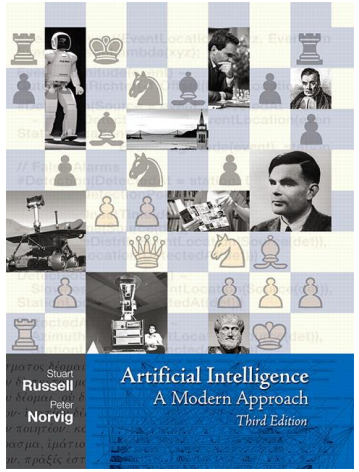
The study and engineering of computations that make it possible to perceive, reason, act, learn and adapt.

Varying Definitions of AI

Not Included in the Main Report

Thinking Humanly	Thinking Rationally
"The exciting new effort to make computers think . . . *machines with minds*, in the full and literal sense." (Haugeland, 1985) "[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning . . ." (Bellman, 1978)	"The study of mental faculties through the use of computational models." (Charniak and McDermott, 1985) "The study of the computations that make it possible to perceive, reason, and act." (Winston, 1992)
Acting Humanly	**Acting Rationally**
"The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil, 1990) "The study of how to make computers do things at which, at the moment, people are better." (Rich and Knight, 1991)	"Computational Intelligence is the study of the design of intelligent agents." (Poole *et al.*, 1998) "AI . . . is concerned with intelligent behavior in artifacts." (Nilsson, 1998)

Source – Artificial Intelligence: A Modern Approach

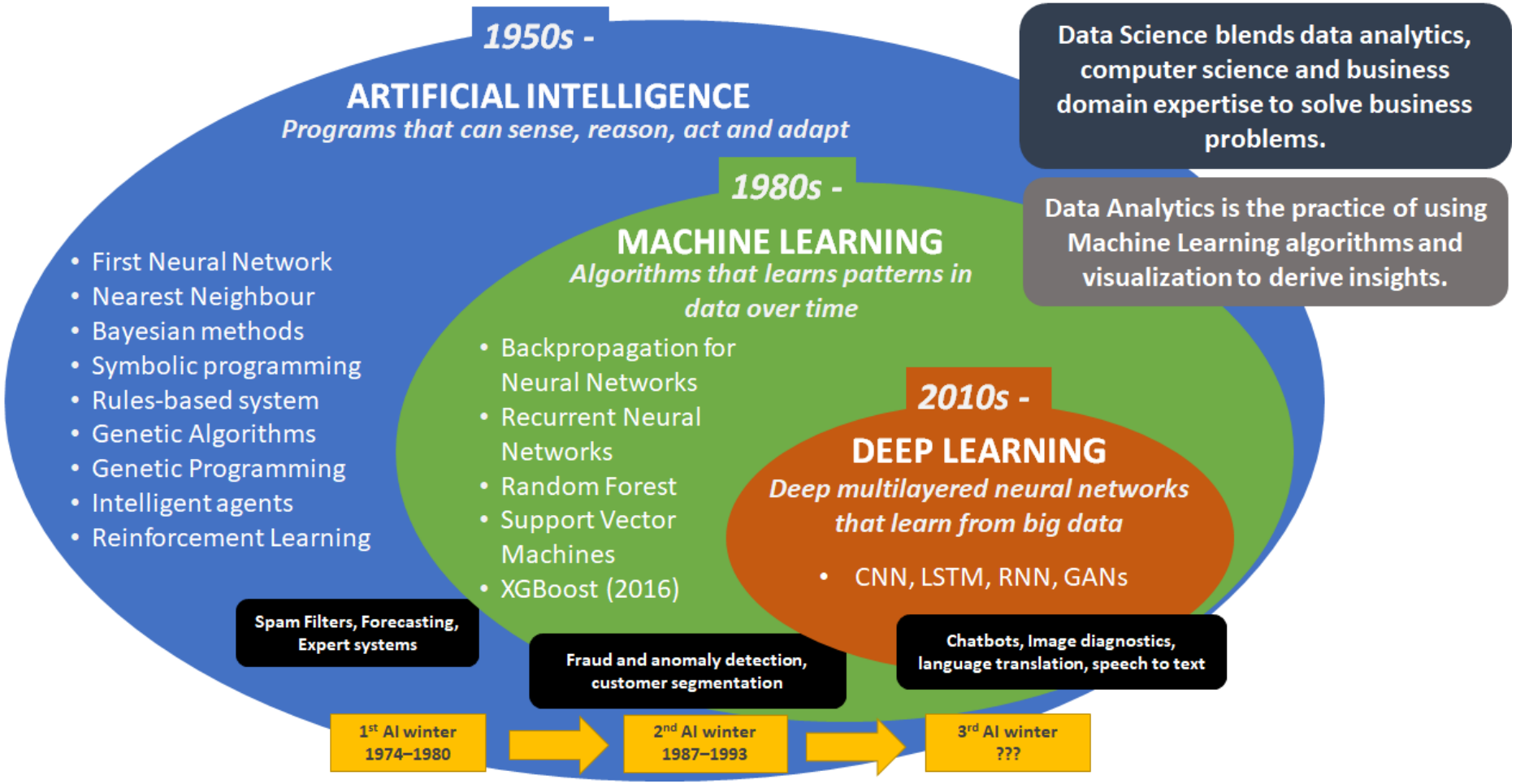


"Artificial Intelligence: A Modern Approach, 3rd Edition," 2010
Stuart Russell and Peter Norvig
Prentice Hall

SG:D EMPOWERING POSSIBILITIES

INFOCOMM MEDIA DEVELOPMENT AUTHORITY

AI VS MACHINE LEARNING VS DATA ANALYTICS VS DATA SCIENCE



Source – AI Singapore presentation

SG:D EMPOWERING POSSIBILITIES

INFOCOMM MEDIA DEVELOPMENT AUTHORITY

EVOLUTION OF AI

Not Included in the Main Report

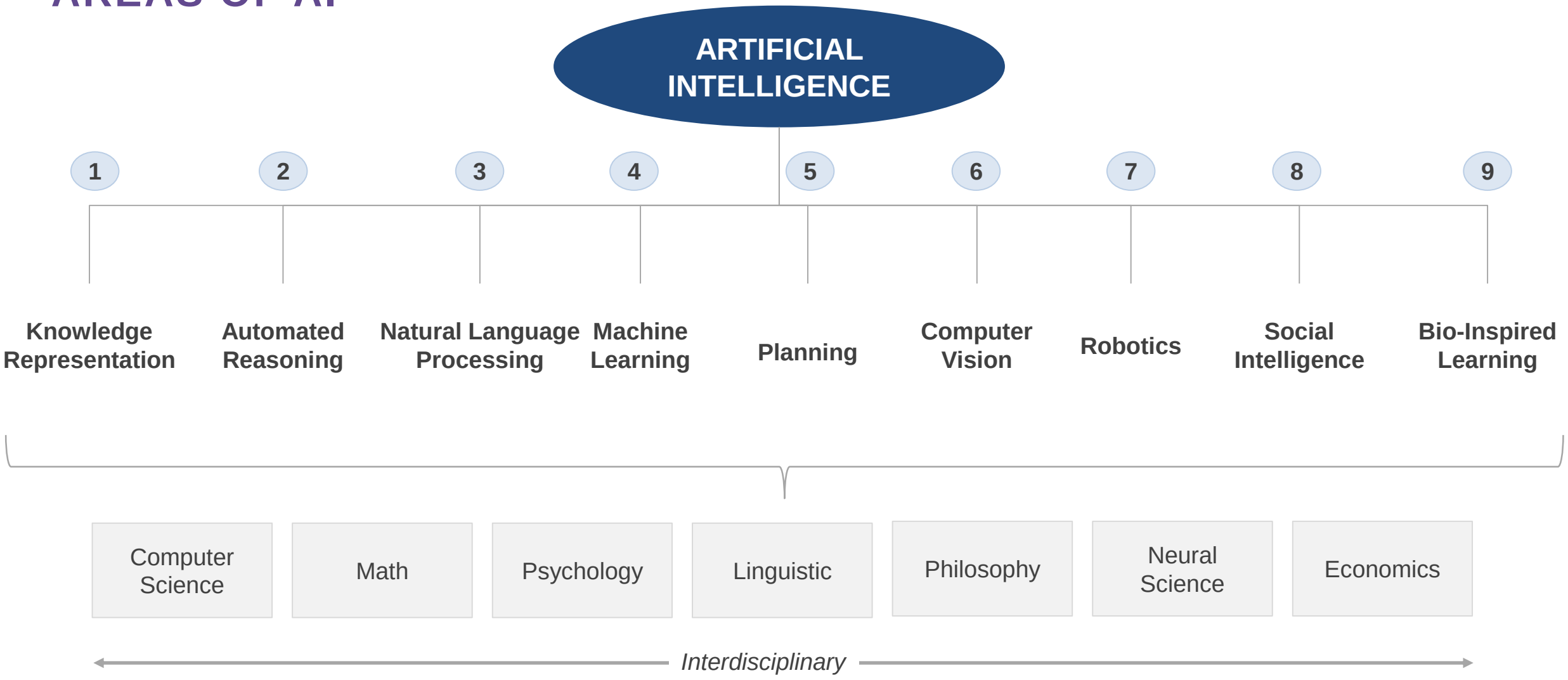
AI Stages	Artificial Narrow Intelligence (ANI)	Artificial General Intelligence (AGI)	Artificial Super Intelligence (ASI)
	Execute specific focused tasks, without ability to self-expand functionality	Perform broad tasks, reason, and improve capabilities comparable to humans	Demonstrate intelligence beyond human capabilities
Timing	**Today**	**About 2040?**	**Soon after AGI**
Implications	Outperform humans in specific repetitive functions, such as driving, medical diagnosis and financial advice	Compete with humans across all endeavors, such as earning university degrees and convincing humans that it is human	Outperform humans, helping to achieve societal objectives or threatening human race

Source – "Defining Artificial Intelligence", Innovation Centre Denmark, Silicon Valley, 2018

SG:D EMPOWERING POSSIBILITIES

INFOCOMM MEDIA DEVELOPMENT AUTHORITY

AREAS OF AI

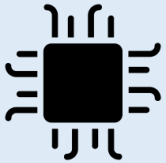


Source – Adaptation of Taiger presentation slides at IMDA workshop, May 2018

AI – KEY/EMERGING TRENDS EXAMINED

Algorithms and Techniques

- Rapid advancements in AI innovation
- Driving diverse applications of AI
- Examples
  - Emotion recognition (advanced image processing or audio data processing)
  - Content creation



Hardware

- AI-optimised hardware
- Graphic and central processing units and processing devices specifically designed and structured to execute AI-oriented tasks

Enablement of Deployment of AI

- AI frameworks, e.g. TensorFlow, Caffe
- Drag-and-drop, no/low-code AI development platforms, e.g. Lobe, Google Cloud AutoML

Enablement of Trust in AI

- Explainable AI
- Frameworks, tools and services to test for bias
- Examples
  - Accenture AI Fairness Tool
  - IBM Supplier's Declaration of Conformity

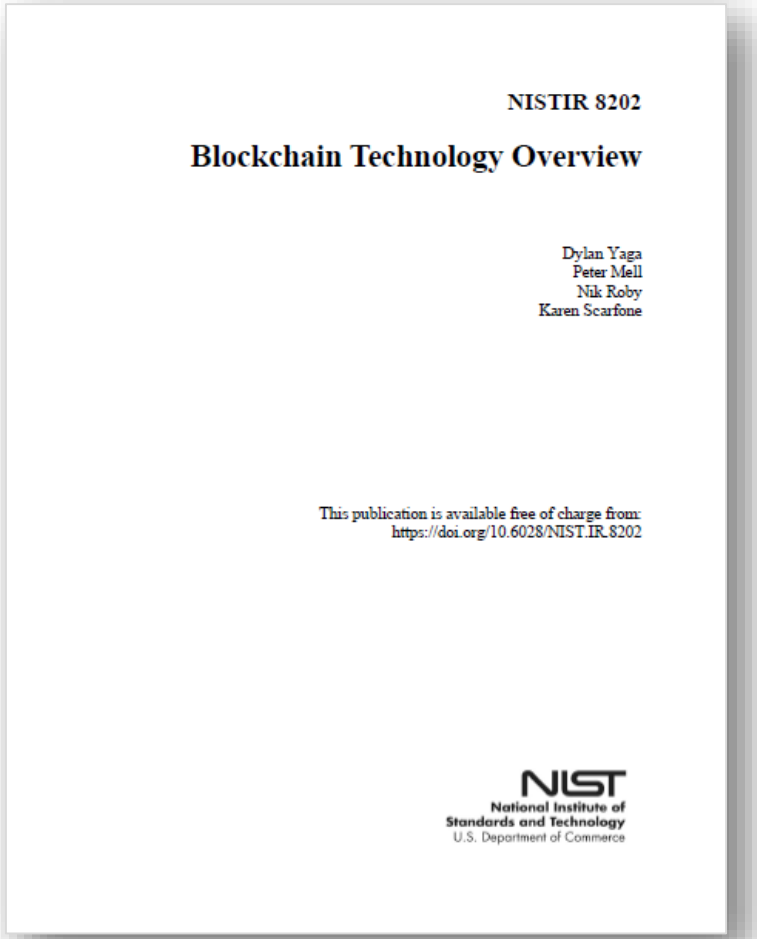
AI is shifting from discovery phase to implementation phase

Developments in making AI more accessible and trusted

DEFINITION OF BLOCKCHAIN

"Blockchains are distributed digital ledgers of cryptographically signed transactions that are grouped into blocks. Each block is cryptographically linked to the previous one (making it tamper evident) after validation and undergoing a consensus decision. As new blocks are added, older blocks become more difficult to modify (creating tamper resistance). New blocks are replicated across copies of the ledger within the network, and any conflicts are resolved automatically using established rules."

- Blockchain Technology Overview
NISTIR 8202
National Institute of Standards and Technology
US Dept of Commerce
Oct 2018


NISTIR 8202

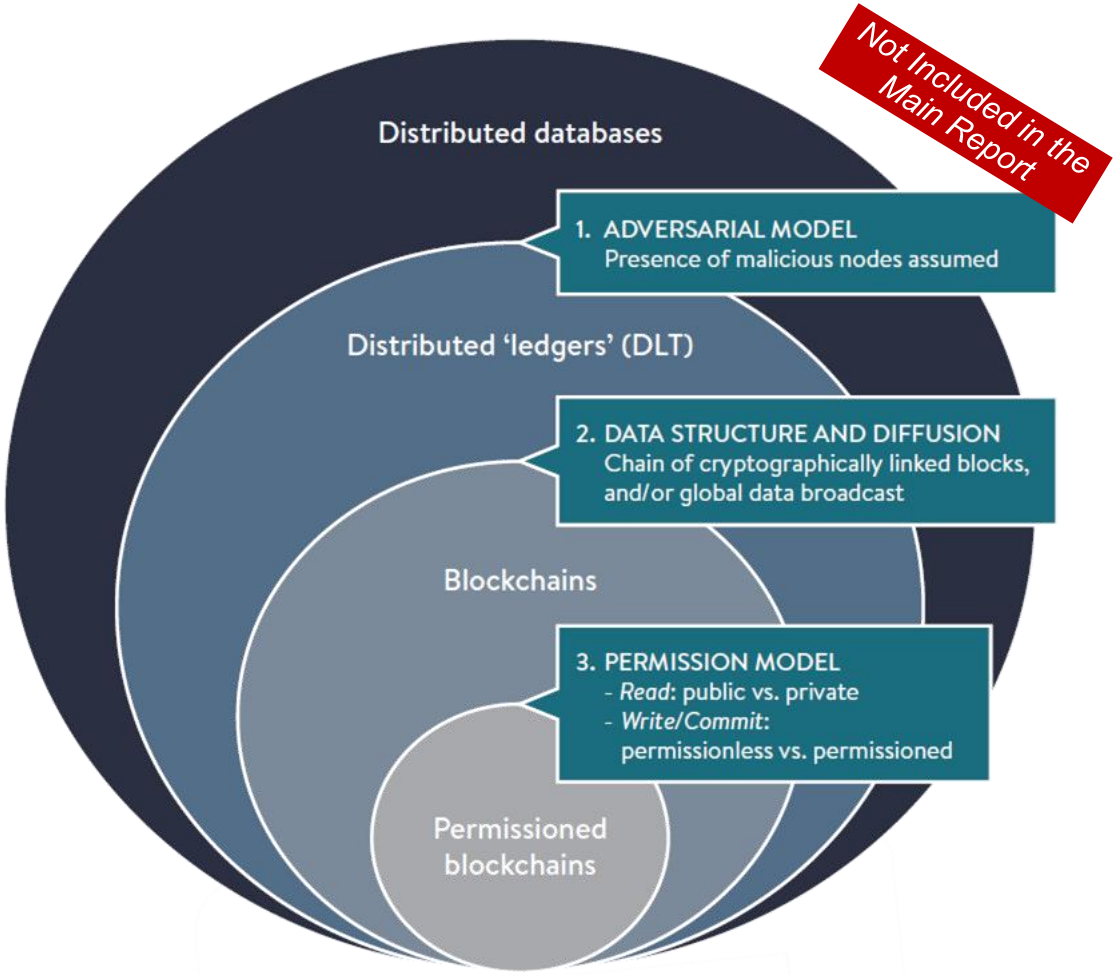
Blockchain Technology Overview

Dylan Yaga
Peter Mell
Nik Roby
Karen Scarfone

This publication is available free of charge from:
https://doi.org/10.6028/NIST.IR.8202

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

"BLOCKCHAIN" VS "DISTRIBUTED LEDGER"



Blockchains and Distributed Ledgers are Types of Distributed Databases

Key Differences btw Distributed Ledger and Traditional Distributed Database

Use of an adversarial threat model, which assumes that not all nodes are honest

Key Differences btw Blockchains and Other Distributed Ledgers

Use of a specific data structure that bundles transactions into blocks, and/or the broadcast of data to all participants

Note:
"Blockchain technology" and "distributed ledger technology" are still commonly used interchangeably despite attempts to semantically separate them by their different underlying architectures

In the context of WG4, WG4 examines the broader distributed ledger technologies, even though "Blockchain" is used in the name of WG44

Source – Global Blockchain Benchmarking Study", Dr Garrick Hileman & Michel Rauchs, 2017

BLOCKCHAIN PERMISSION MODELS

Not Included in the Main Report

Blockchain types		Read	Write	Commit
Open	*Public permissionless*	Open to anyone	Anyone	Anyone*
Open	*Public permissioned*	Open to anyone	Authorised participants	All or subset of authorised participants
Closed	*Consortium*	Restricted to an authorised set of participants	Authorised participants	All or subset of authorised participants
Closed	*Private permissioned ('enterprise')*	Fully private or restricted to a limited set of authorised nodes	Network operator only	Network operator only

Operate in a 'hostile' environment with unknown actors, requiring the use of *'crypto-economics'* to incentivise participants to behave honestly (e.g., by rewarding miners with tokens native to the system, such as bitcoins) and to keep the network censorship-resistant

Operate in an environment where participants are already known and vetted, which removes the need for a native token to incentivise good behaviour. Participants are held liable through off-chain legal contracts and agreements, and are incentivised to behave honestly via the threat of legal prosecution in the case of misbehaviour.

Source – Global Blockchain Benchmarking Study", Dr Garrick Hileman & Michel Rauchs, 2017

EVOLUTION OF BLOCKCHAIN

Not Included in the Main Report

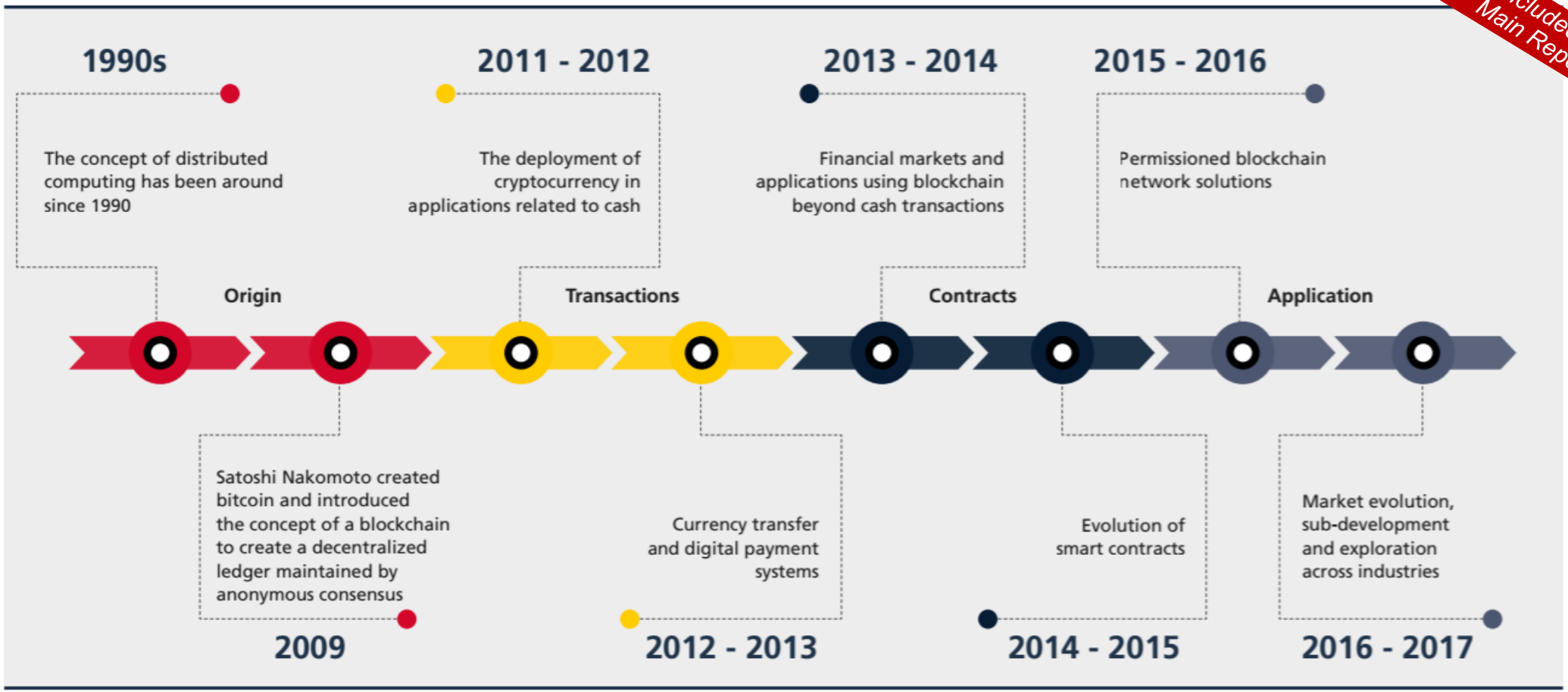


Figure 2: A history of blockchain technology; **Source:** Accenture

Source – Blockchain in Logistics, DHL & Accenture, 2018

BLOCKCHAIN – KEY/EMERGING TRENDS EXAMINED (1/2)

Decentralised Architecture

- Evolution of blockchain governance
- Existing dominant blockchain: Off-chain governance, e.g. Ethereum
- Emerging: On-chain governance, e.g. Tezos

Network

- Approaches to enhance scalability, e.g. Layer 1, Layer 2
- Alternative distributed ledgers, e.g. DAGs
- Customised hardware and ASIC-resistant consensus
- Enhancements on consensus algorithms

Security and Privacy

- End point/wallet security
- Trusted Execution Environment (TEE)
- Security frameworks
- Privacy, e.g. zero-knowledge proof, ring signatures

Smart Contracts

- Tools to enable smart contract creation
- Smart contract security
- Privacy-preserving smart contracts
- Ai-powered smart contracts

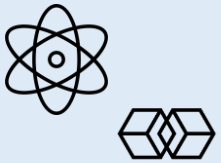
Blockchain still in discovery phase

Developments in enhancing Blockchain technology (e.g. scalability) and understanding implications (e.g. governance)

BLOCKCHAIN – KEY/EMERGING TRENDS EXAMINED (2/2)

Blockchain Interoperability

- Cross-chain technologies and initiatives
- Interoperability efforts, e.g. Blockchain Interoperability Alliance (BIA)



Post-Quantum Blockchain

- Quantum-proofing new blockchains
  - Post-quantum cryptographic schemes
  - Blockchains using quantum cryptography
- Quantum-proofing existing blockchains
  - Replacement of vulnerable algorithms
  - Secure transition strategies

Standards Development

- Short term: Standardisation of terminology and vocabulary
- Medium term: Interoperability
- Longer term: Technical aspects

Blockchain still in discovery phase

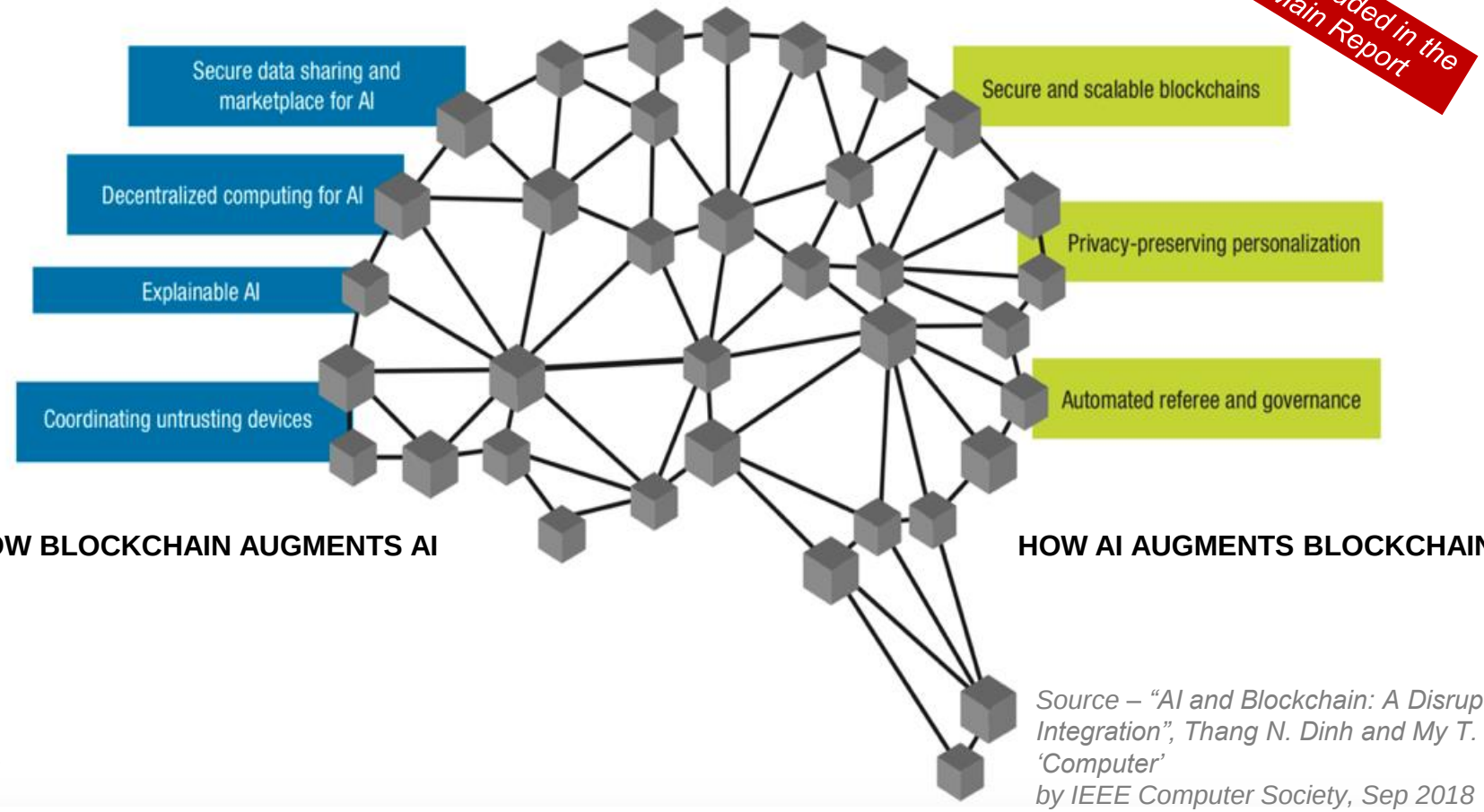
Developments in enhancing Blockchain technology (e.g. scalability) and understanding implications (e.g. governance)

TECHNOLOGICAL CONVERGENCE (1/2)

Not Included in the Main Report

HOW BLOCKCHAIN AUGMENTS IOT

- Authentication and validation of nodes
- Enable data provenance
- Create incentive structure to share IoT data



HOW BLOCKCHAIN AUGMENTS AI

HOW AI AUGMENTS BLOCKCHAIN

Source – "The Blockchain-Enabled Intelligent IoT Eocnomy", Forbes, Sep 2018

Source – "AI and Blockchain: A Disruptive Integration", Thang N. Dinh and My T. Thai, 'Computer' by IEEE Computer Society, Sep 2018

TECHNOLOGICAL CONVERGENCE (2/2)

HOW AI AUGMENTS CYBERSECURITY

CYBERSECURITY THREATS TABLE: OLD-SCHOOL VS. AI

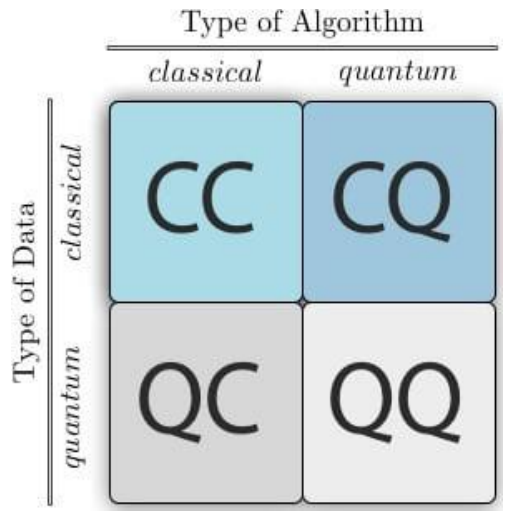
CYBERSECURITY THREAT(S)	OLD-SCHOOL APPROACH	NEW-SCHOOL AI APPROACH	SELECT STARTUPS LEVERAGING AI APPRAOCH
Malware	- **Anti-virus etc. uses signature-based detection to flag attacks** - Covers known vulnerabilities	- **Pattern recognition and predictive analytics to thwart new attacks** - Can cover "zero-day" exploits	CYLANCE patternex SentinelOne
DDoS (Distributed Denial Of Service)	- **Analysts monitor network-traffic to spot an on-going DDoS attack** - Resource intensive, limited by human cognition, reactive	- **Algorithms auto-detect abnormal network-resource allocation** - Efficient analyst resources, automated, faster response	VECTRA ZENEDGE SHAPE SECURITY
IoT & Endpoints	- **Manual device-level security updates through the cloud** - Ad-hoc security, ineffective at scale	- **Network-level behavior-analytics and entity-anomaly-detection** - Real-time security, effective at scale	FORTSCALE TANIUM CUJO
Social Engineering	- **Education on digital hygiene and countering hackers' tactics** - Prone to human error	- **Education + social-biometrics and user-anomaly-detection** - Less prone to human error	BehavioSec RUBICA sqrrl

CBINSIGHTS

Source – "Old-School vs New-School: How Artificial Intelligence is Transforming Cybersecurity", CBInsights, Jul 2017

CONVERGENCE OF QUANTUM COMPUTING AND AI

Not Included in the Main Report



Approaches to Machine Learning as a Result of Convergence

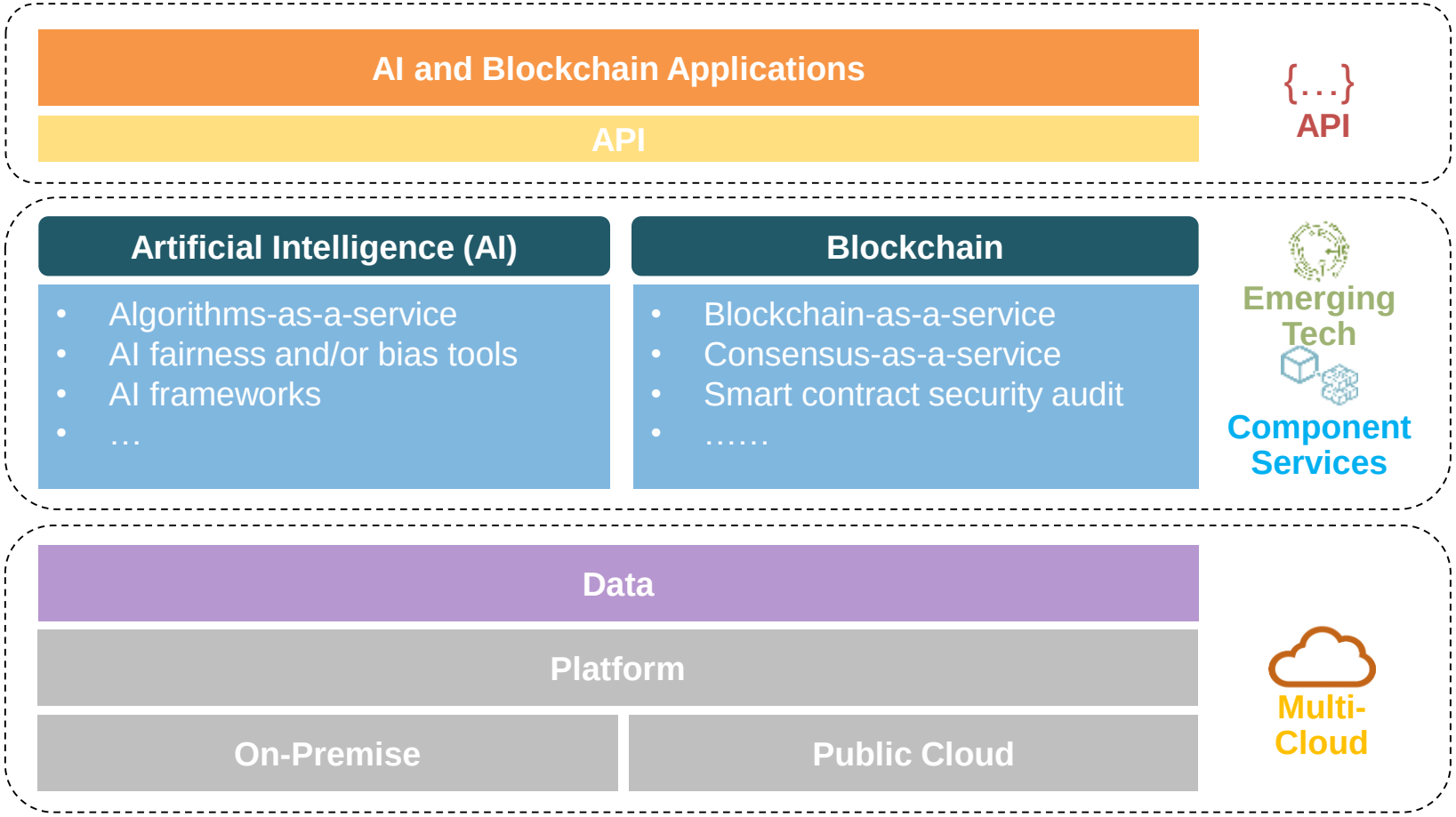
Source – "How Quantum Computing and Machine Learning Work Together", Hackernoon, Jun 2018

SG:D EMPOWERING POSSIBILITIES

INFOCOMM MEDIA DEVELOPMENT AUTHORITY

DEEP TECH IN DEEP CLOUD

AI AND DATA, AND BLOCKCHAIN



Source: IMDA

1 AI Software

1.1 **Abstracted, higher-level AI toolkit and software for less experienced developers or business users**
1.2 **AI fairness and/or bias tools**

Software and services to enable deployment and trust AI.

2 Blockchain

2.1 **Layer 1 and Layer 2 scalability mechanisms**
2.2 **Blockchain interoperability**
2.3 **New governance mechanisms, e.g. on-chain governance**
2.4 **Graphical smart contract editors**
2.5 **Smart contract security analysis**
2.6 **Privacy preserving smart protocols & platforms**

Software and services to enable deployment to grow Blockchain usability and adoption, and trust in Blockchain.

3 Specialised Compute for AI

4.1 **Special-purpose cloud**
4.2 **Chipsets, e.g. GPU, FPGA, custom ASICs**
4.3 **Edge compute**

Dedicated hardware will provide the computational abilities and/or architecture to make it possible to run AI algorithms within a reasonable period of time.

SWOT ANALYSIS

STRENGTHS

1. Pro-business environment
2. Internationally trusted legal system and IP framework
3. Political stability
4. Technologically savvy consumers
5. Pro-open source environment, which has contributed to driving innovation in Singapore, e.g. in blockchain

WEAKNESSES

1. Small domestic market
2. Small population size constrains the volume of data available for AI model development

OPPORTUNITIES

1. AI research – Singapore universities amongst the top in ranking in citation impact[1]
2. Shift of AI from discovery phase to implementation phase[2] – Opportunities for Singapore to reap economic benefits of AI through driving adoption
3. Recognised as one of the top blockchain hubs[3] globally, creating opportunities for thought leadership
4. Neighbouring countries in ASEAN with large populations present tech providers in Singapore with ripe opportunities for technology adoption

THREATS

1. Need for Singapore to constantly keep abreast, due to dynamic and fast-moving pace of technological advancements globally and in neighbouring countries
2. Relatively more urgent need, compared to neighbouring countries in ASEAN, to address job displacement from technologies including AI and robotics[4]

NOTE: 1) “NTU Ranks Top 3 Globally in Citation Impact of AI Research”, NTU, May 2017; 2) “What China can Teach the US about Artificial Intelligence”, New York Times, Sep 2018; “5 Reasons why Singapore is a Famous Hub for Blockchain and Crypto Conferences”, CoinStaker, Sep 2018; 4) A 2018 study conducted by Cisco and Oxford Economics indicated that within Southeast Asia, Singapore will be worst-hit by job displacement arising from technologies – Nearly 21% of full-time workers could be impacted

WG4 RECOMMENDATIONS

INTEGRATING ECOSYSTEMS

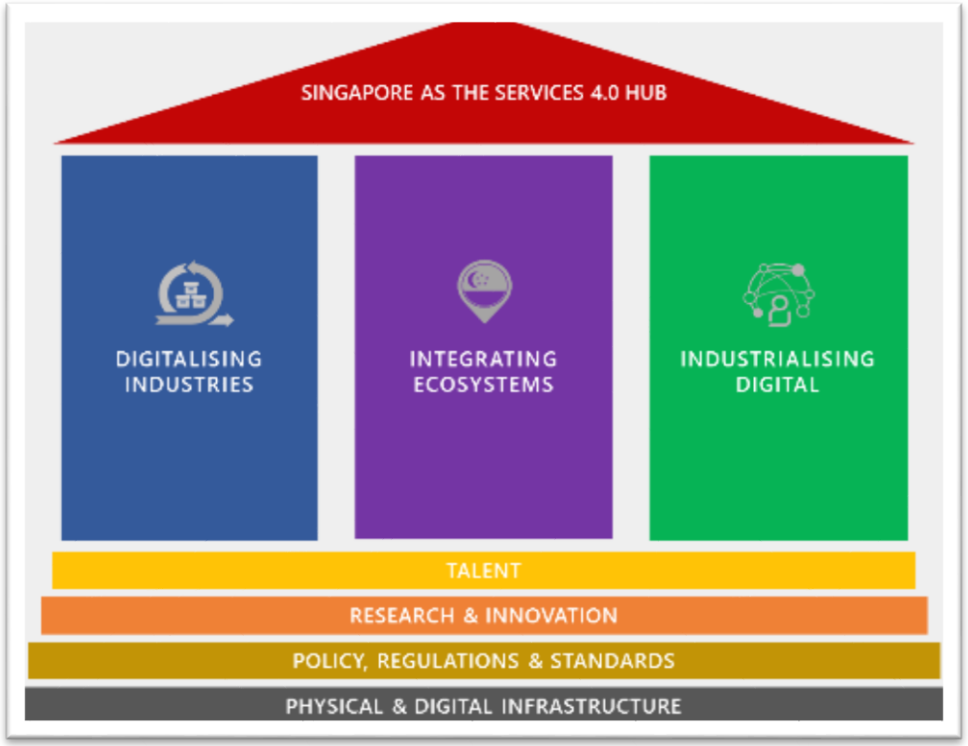
- Encourage formation of Blockchain ecosystems to encourage collaboration

POLICY, REGULATION & STDS

- Formation of Blockchain governance think tank to understand implications of decentralisation

PHYSICAL & DIGITAL INFRA

- Develop platforms to enable delivery of AI productised as API services
- Develop computational infrastructure for AI and other compute-intensive technologies



INDUSTRIALISING DIGITAL

- Development of capabilities, tools and services to support responsible AI deployment
- Development of capabilities, tools and services in Blockchain security

TALENT

- Organize AI training programme (e.g. AI Apprenticeship Programme (AIAP) by AI.SG) and AI workshops (e.g. “How to Use AI to Grow Your Business” by IMDA) for enterprises and professionals

RESEARCH & INNOVATION

- Invest in inter-disciplinary AI and Blockchain research across technologies, e.g. cybersecurity & AI, quantum computing & AI

New recommendation Existing strategy

Source: IMDA

THANK YOU

sgdigital.sg

twitter.com/IMDAsg

facebook.com/IMDAsg

youtube.com/IMDAsg

SG:D
EMPOWERING POSSIBILITIES

INFOCOMM MEDIA DEVELOPMENT AUTHORITY