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N2C2M2 Validation using abELICIT: Design and Analysis of ELICIT runs using software agents

17th ICCRTS: "Operationalizing C2 Agility"

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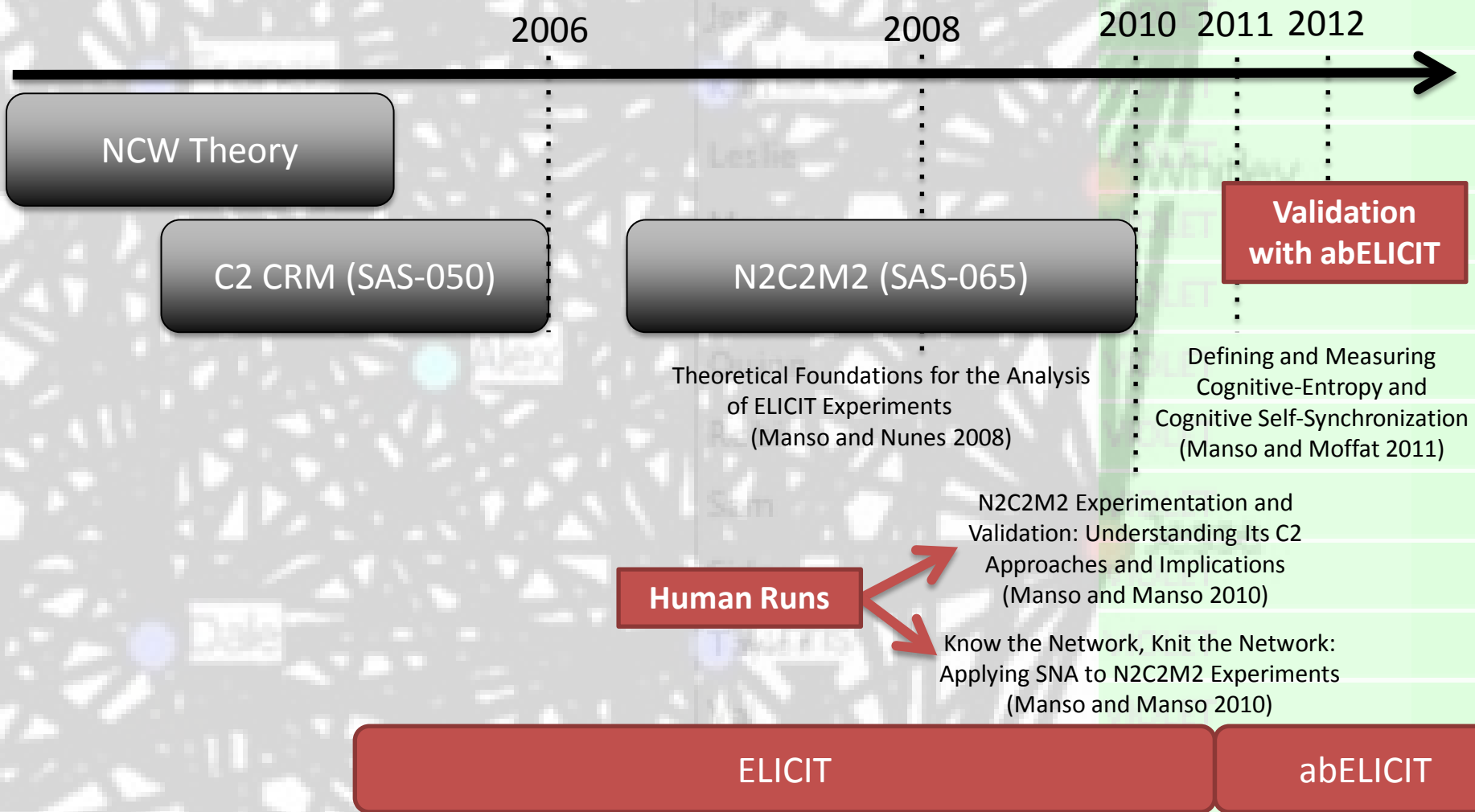
Agenda

- Introduction and Background
- Formulation of the Experiments
- Analysis
- Conclusions
- Bibliography

Introduction

- Validation of the N2C2M2

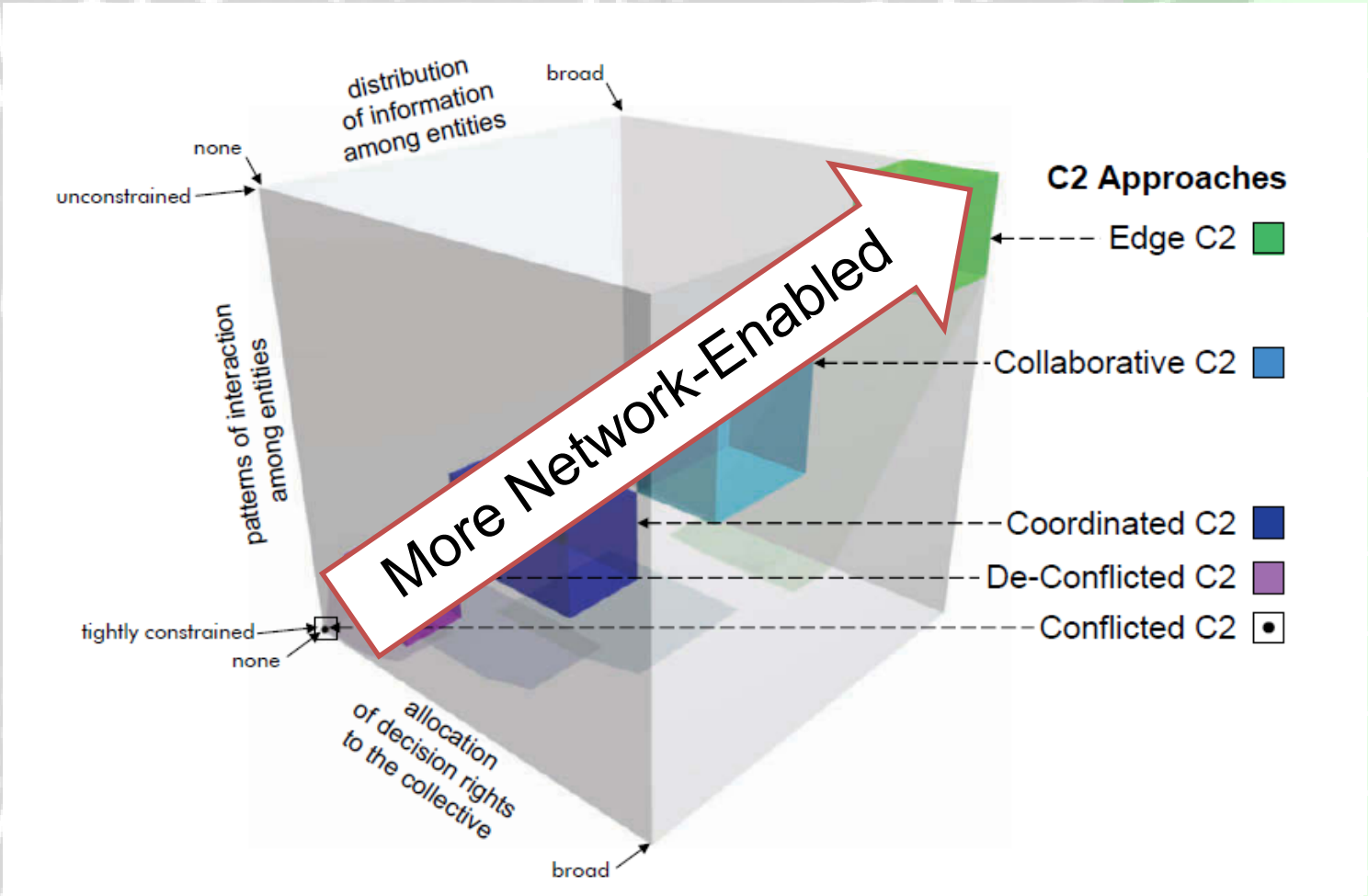


Introduction

- Theory of NCW
  - NCW Tenets
  - NCW Value Chain
- C2 Conceptual Reference Model
  - ASD-NII/OFT
  - NATO SAS-050
- C2 Approach Space and its three key-dimensions: Allocation of Decision Rights (ADR), Patterns of Interaction (PI) and Distribution of Information (DI).
- **NATO NEC C2 Maturity Model (SAS-065)**
  - Five C2 Approaches

Introduction

NATO NEC C2 Maturity Model (SAS-065 2010)



Source: SAS-065 2010

Introduction

NATO NEC C2 Maturity Model hypothesises that

- the more network-enabled a C2 approach is *the more likely it is to develop shared awareness and shared understanding* (SAS-065 2010, 69).

Introduction

ELICIT

Experimental Laboratory for
Investigating Collaboration, Information-sharing, and Trust

- CCRP sponsored the design and development of the ELICIT platform to facilitate experimentation focused on information, cognitive, and social domain phenomena
- ELICIT is a web-accessible experimentation environment supported by software tools and instructions / procedures
- abELICIT is an agent-based version of the ELICIT platform

Original slide from (Alberts and Manso 2012)

Introduction

ELICIT

- The goal of each set of participants is to build situational awareness and identify the who, what, when, and where of a pending attack
  - Factoids are periodically distributed to participants; each participant receives a small subset of the available factoids
  - No one is given sufficient information to solve without receiving information from others
  - Participants can share factoids directly with each other, post factoids to websites, and by “keyword directed” queries
  - Participants build awareness and shared awareness by gathering and cognitively processing factoids
- The receiving, sharing, posting, and seeking of factoids and the nature of the interactions between and among participants can be constrained
- Participants can be “organized” and motivated in any number of ways
- Various stresses can applied (e.g. communications delays and losses)
- Software-Agents are used instead of humans

Original slide from (Alberts and Manso 2012)

Introduction

Past Research

- A first and preliminary experimentation stage using two pre-existing models: Hierarchy and Edge (SAS-065 2010).

26 runs (human subjects).

Edge organizations were **more effective, faster, shared more information and were more efficient** than **Hierarchies**.

- A second experimentation stage that recreated the N2C2M2 five C2 approaches (Manso and B. Manso 2010).

18 runs (human subjects).

Edge reached the best scores in the **Information and Cognitive Domains**, but it was surpassed by **Collaborative** in the **Interactions Domain and Measures of Merit** (MoMs). **Conflicted** performed worst in all assessed variables.

Formulation of the Experiments

- Hypotheses

[1] *For a complex endeavor, more network-enabled C2 approaches are more effective than less network-enabled C2 approaches.*

[2] *For a given level of effectiveness, more network-enabled C2 approaches are more efficient than less network-enabled C2 approaches.*

More network-enabled C2 approaches exhibit increased/better levels of:

- [4] *Shared Information;*
- [5] *Shared Awareness;*
- [6] *Self-Synchronization (at cognitive level);*

Than: less network-enabled C2 approaches

[7] *A minimum level of maturity is required to be effective in ELICIT.*

Formulation of the Experiments

- Hypotheses (not covered)

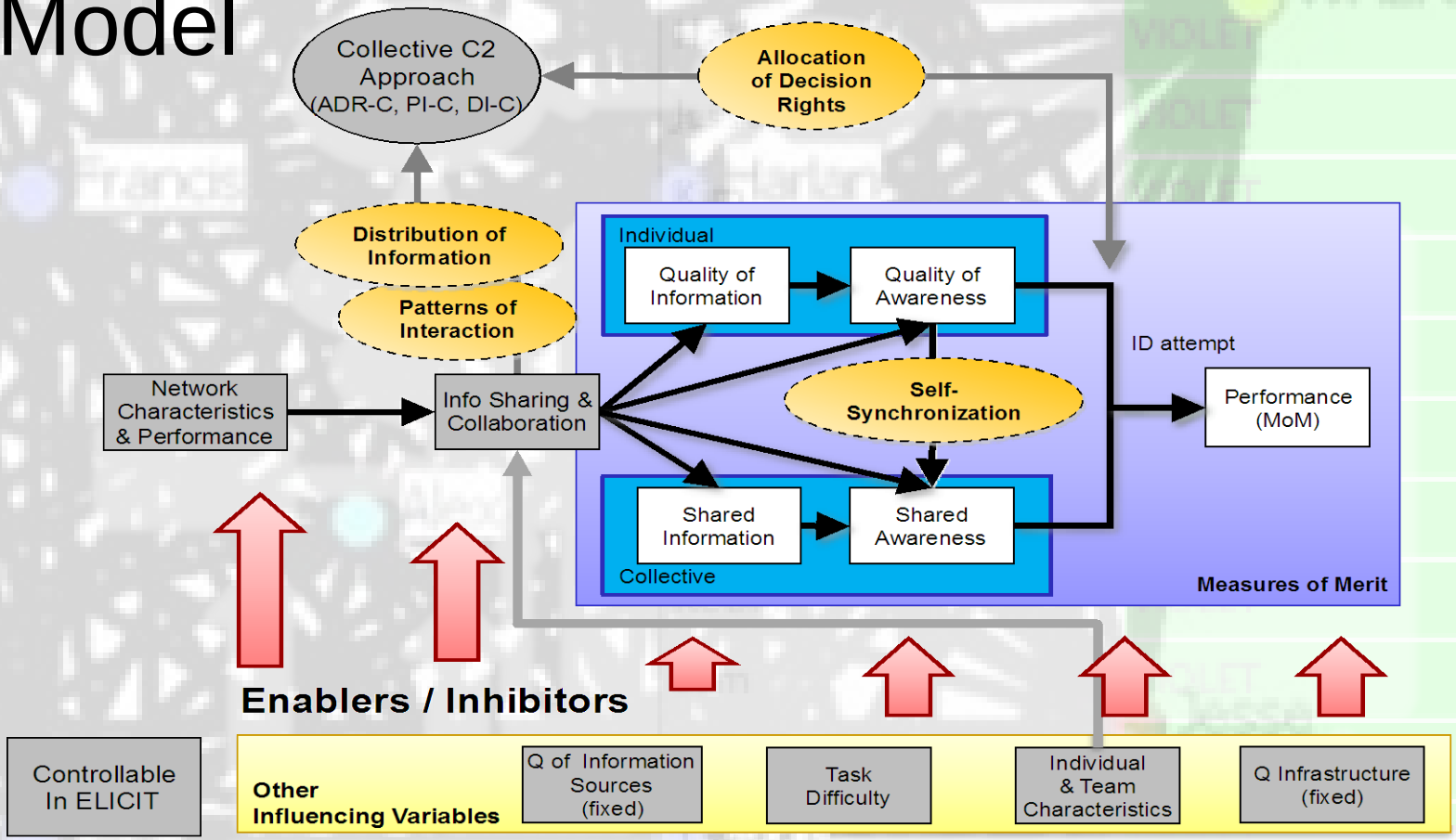
[3] *More network-enabled C2 approaches have more agility than less network-enabled C2 approaches.*

[8] *Increasing the degree of difficulty in ELICIT requires organizations to increase their network-enabled level to maintain effectiveness in ELICIT*.

These are covered in (Alberts and Manso 2012).

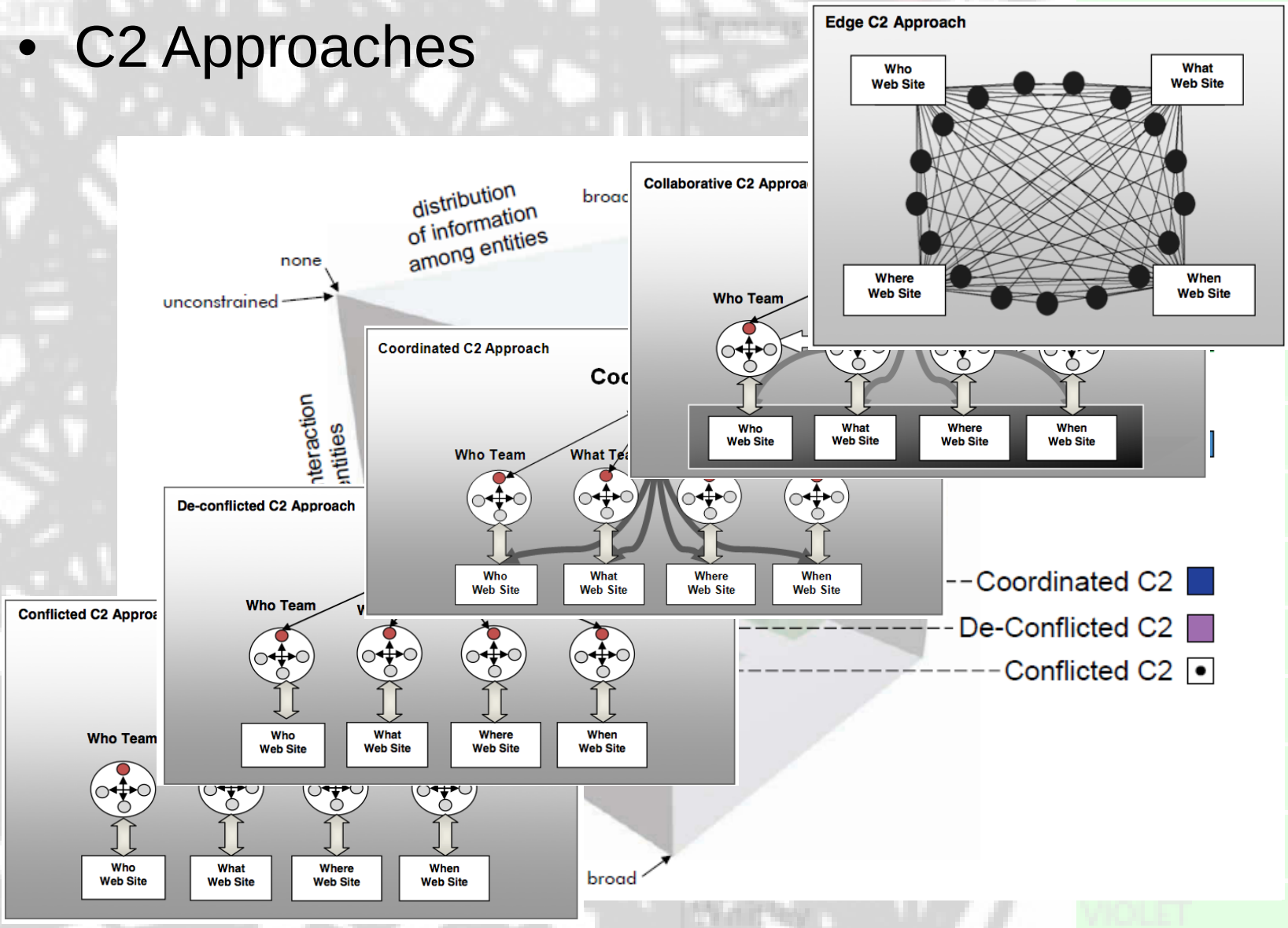
Formulation of the Experiments

- Model



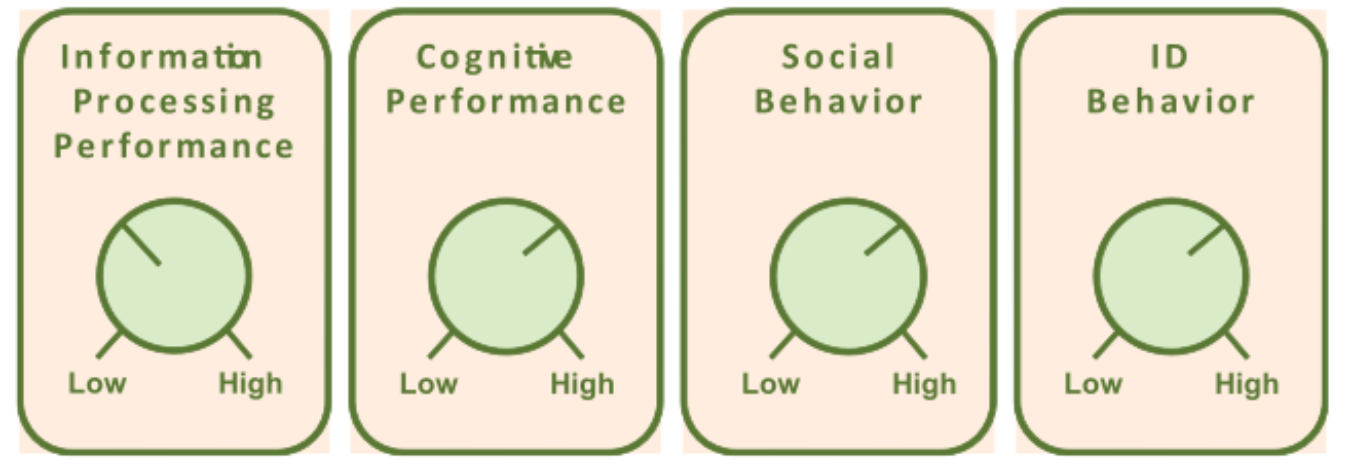
Formulation of the Experiments

- C2 Approaches



Formulation of the Experiments

- Defining the Agents Parameters



The average agent
- 'average' performance (i.e., number of shares, post, pulls and identifications close to human behavior)
- sufficient information processing and cognitive capabilities
- This agent does not hoard information.

Low performing agent

High performing agent

Image source: Upton *et al* 2011

Formulation of the Experiments

- Runs are conduced
  - Per C2 Approach
  - By combining different agent archetypes among the orgnization roles (i.e., top-level, mid-level and bottom-level)
- Resulting in a total of 135 runs

C2 Approach	Agent Type: Top-Level	Agent Type: Mid Level	Agent Type: Bottom-Level	# Possible Combinations*	Run Number
Conflicted C2	1 Coord	4 TLs	12 TMs	27	1 .. 27
De-conflicted C2	1 Deconf	4 TLs	12 TMs	27	28 .. 54
Coordinated C2	1 CTC	4 TLs	12 TMs	27	55 .. 81
Collaborative C2	1 CF	4 TLs	12 TMs	27	82 .. 108
Edge C2	-	-	17 TMs	27**	109 .. 135
			TOTAL	**135**	

* Possible agent types are: (i) baseline, (ii) low-performing and (iii) high-performing

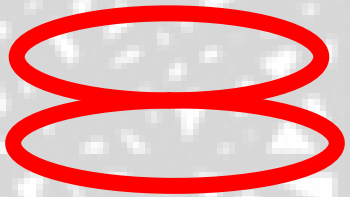
** Use same combinations of agent types in Edge as for other C2 approaches

Analysis

- Information Domain

C2 Approach Number

0



OBS: Shared Information reached maximum value is 68

Analysis

- Information Domain

C2 Approach Number	Top-Level (CTC)	Mid-Level (Who TL)	Mid-Level (What TL)	Mid-Level (Where TL)	Mid-Level (When TL)
1	4	16	16	16	16
2	20	20	20	20	20
3	68	20	20	20	20
4	68	68	68	68	68
5	-	-	-	-	-

Analysis

- Interactions / Social Domain

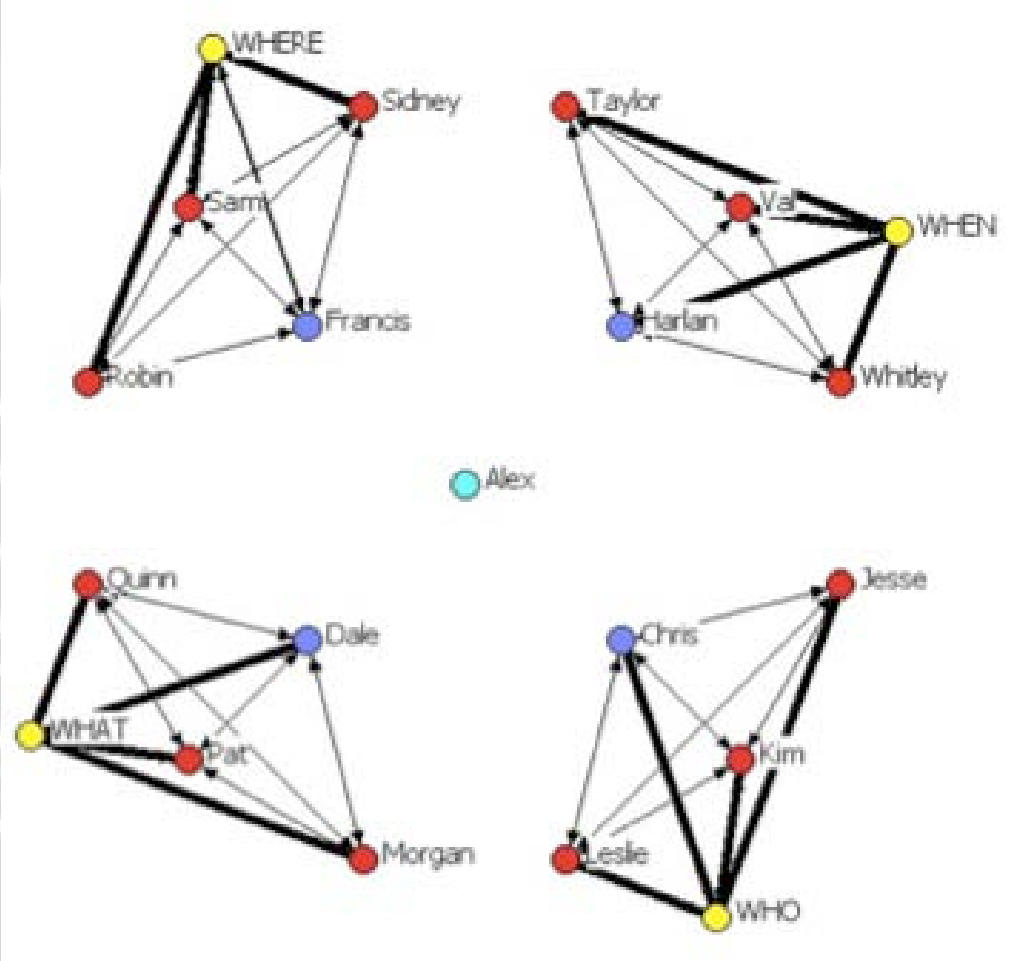
C2 Approach Number

%

0.00

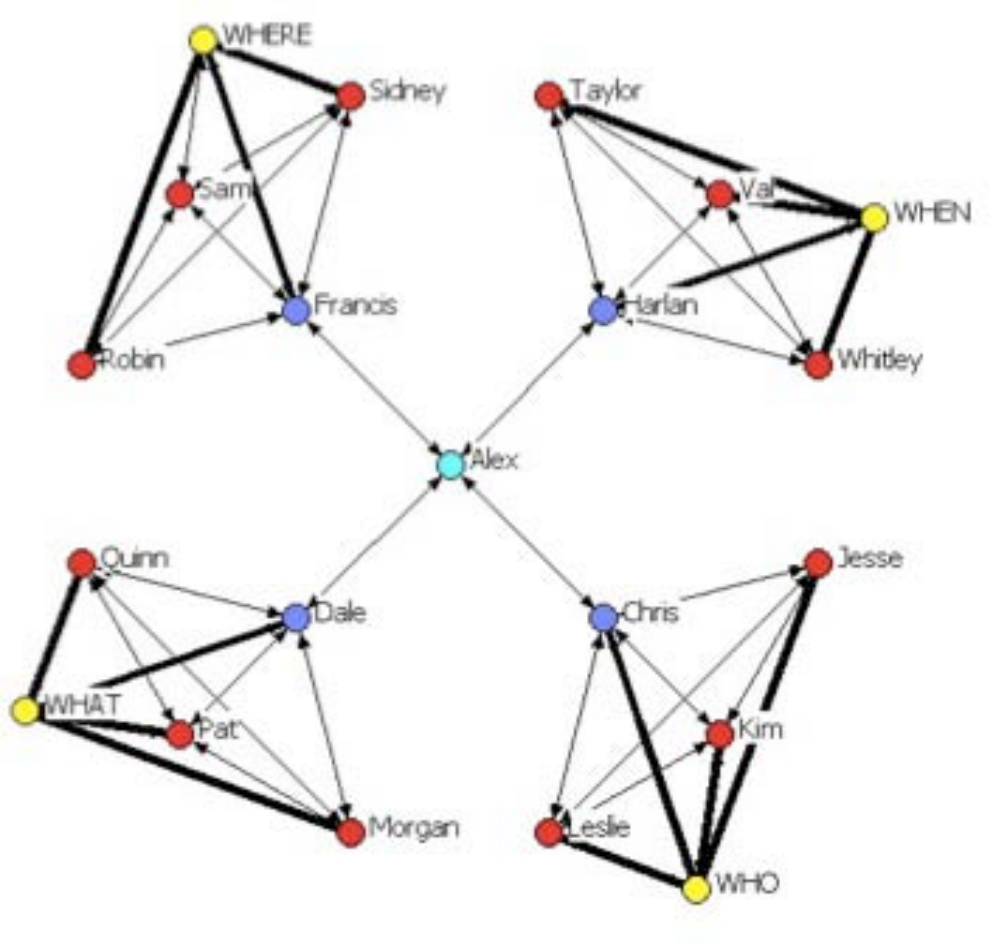
Analysis

- Sociogram: Conflicted C2



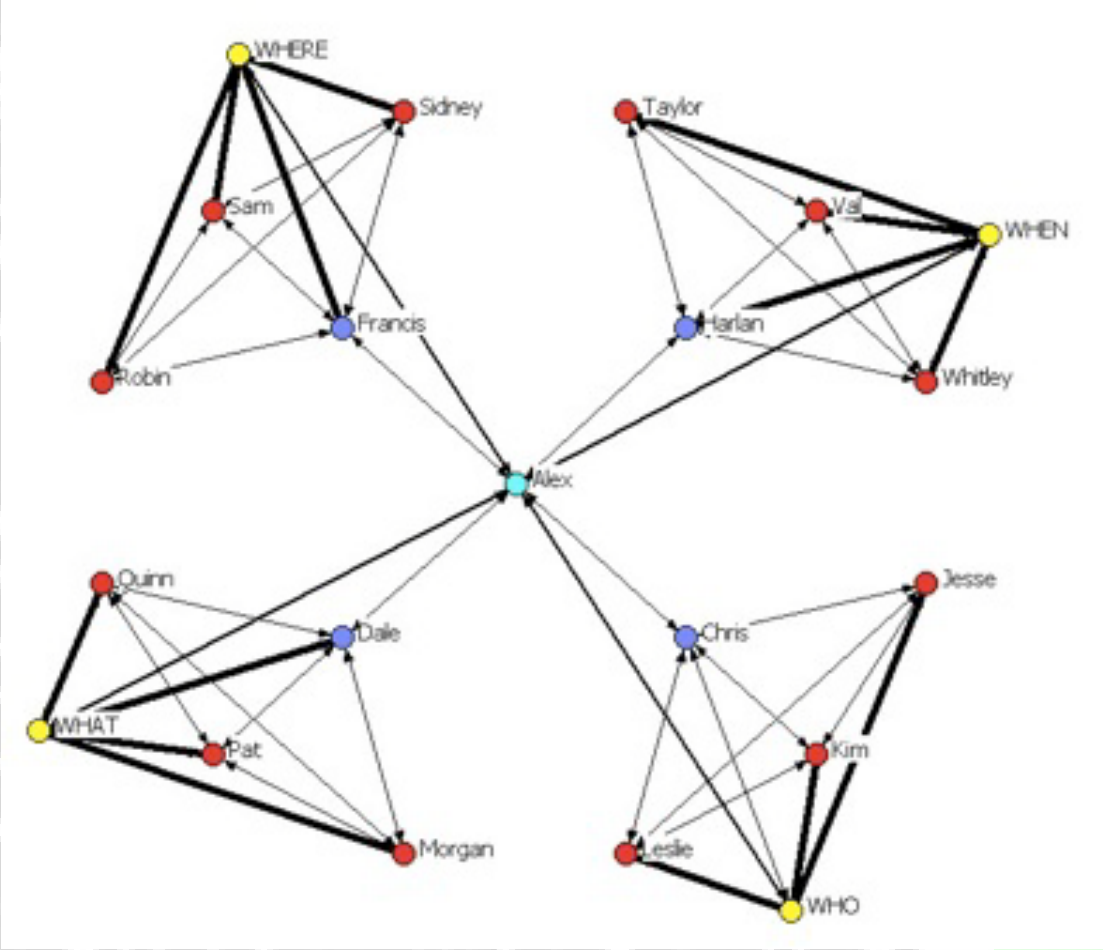
Analysis

- Sociogram: De-Conflicted C2



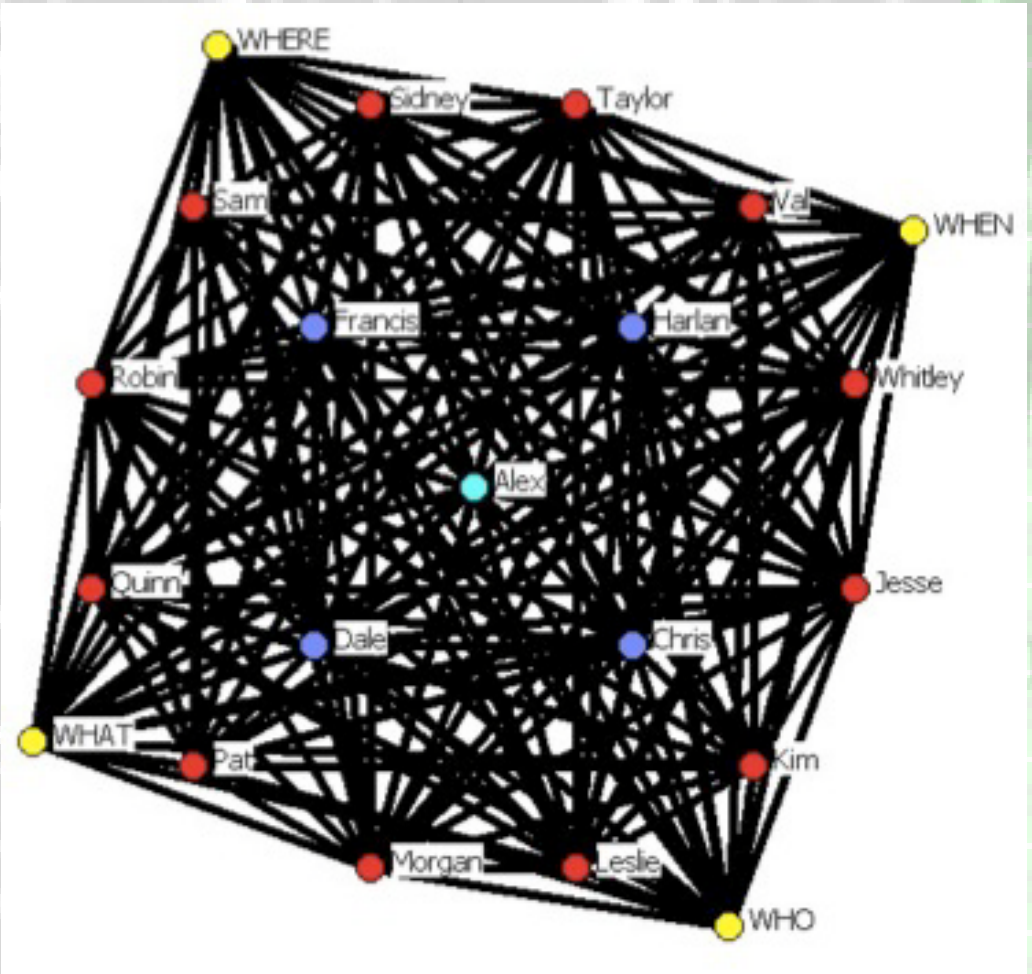
Analysis

- Sociogram: Coordinated C2



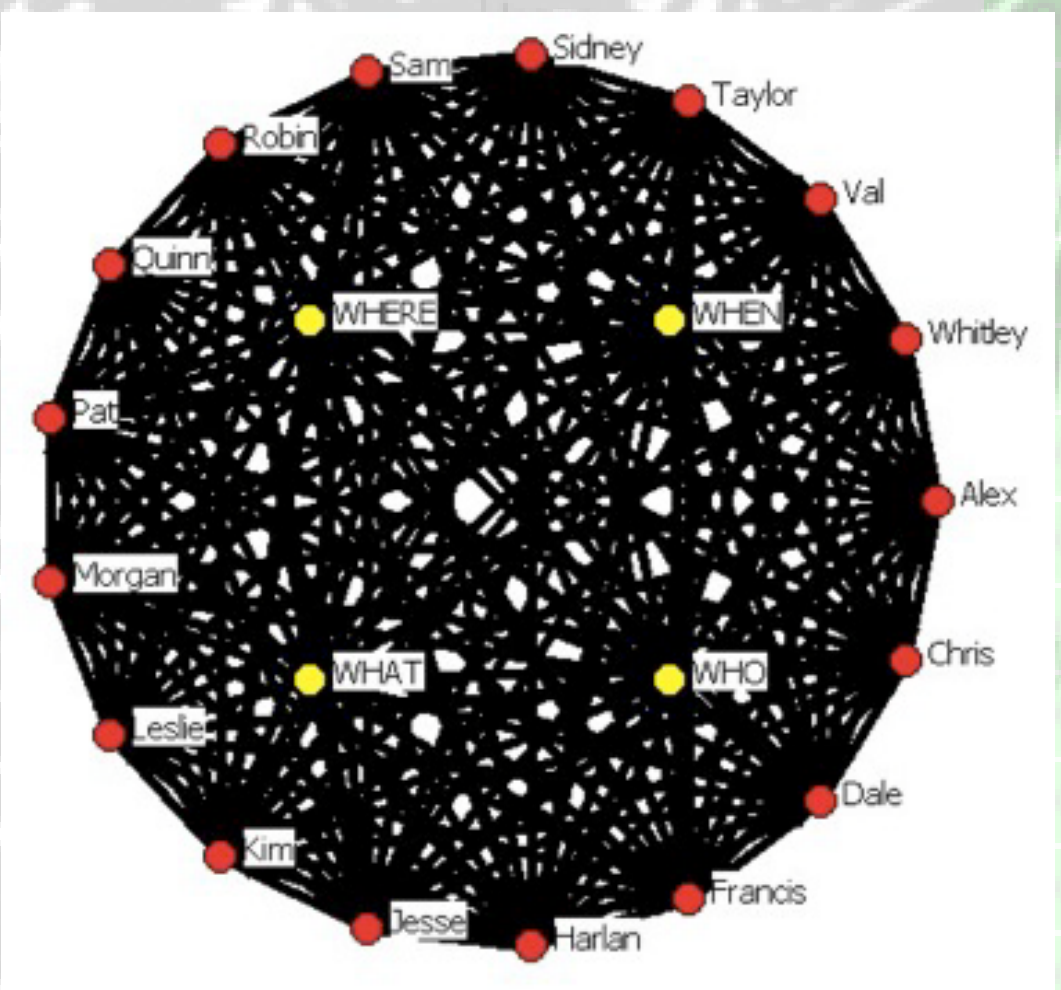
Analysis

- Sociogram: Collaborative C2



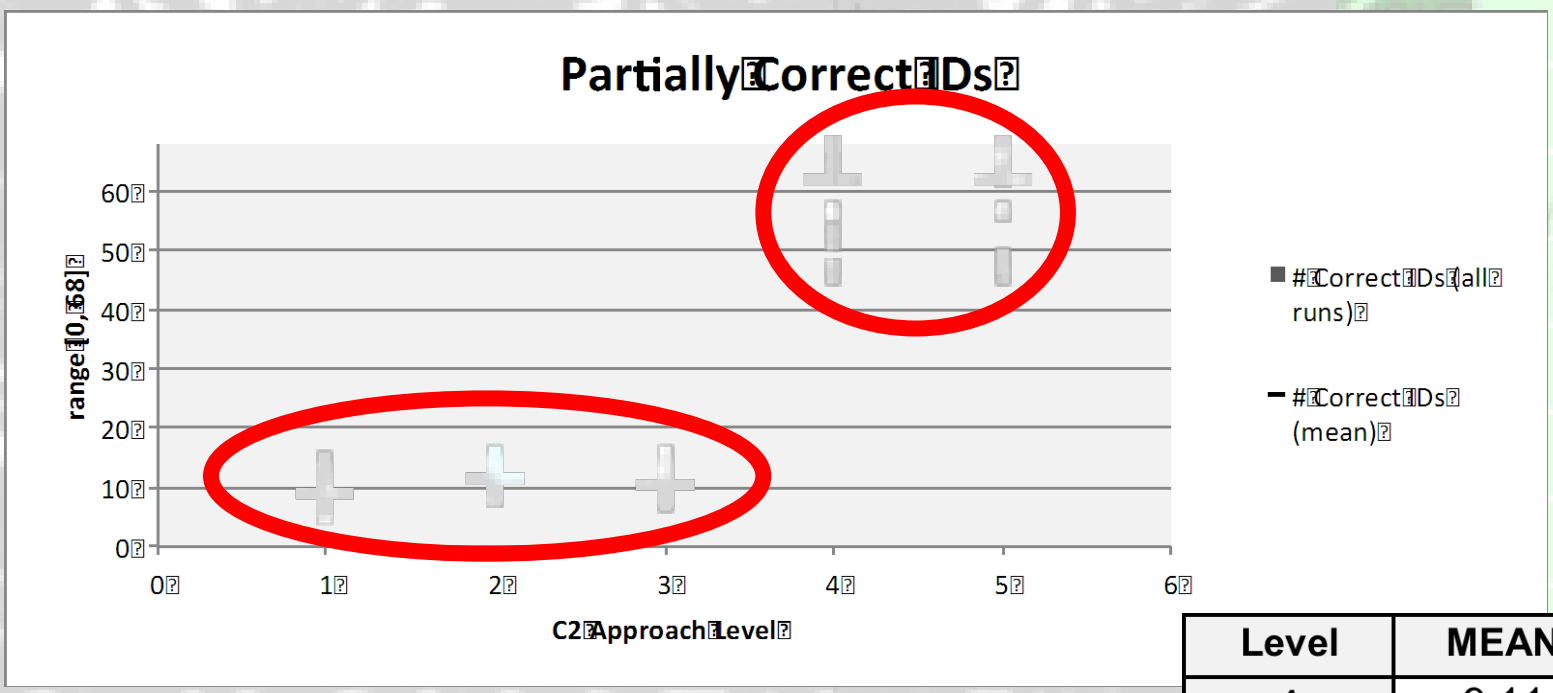
Analysis

- Sociogram: Edge C2



Analysis

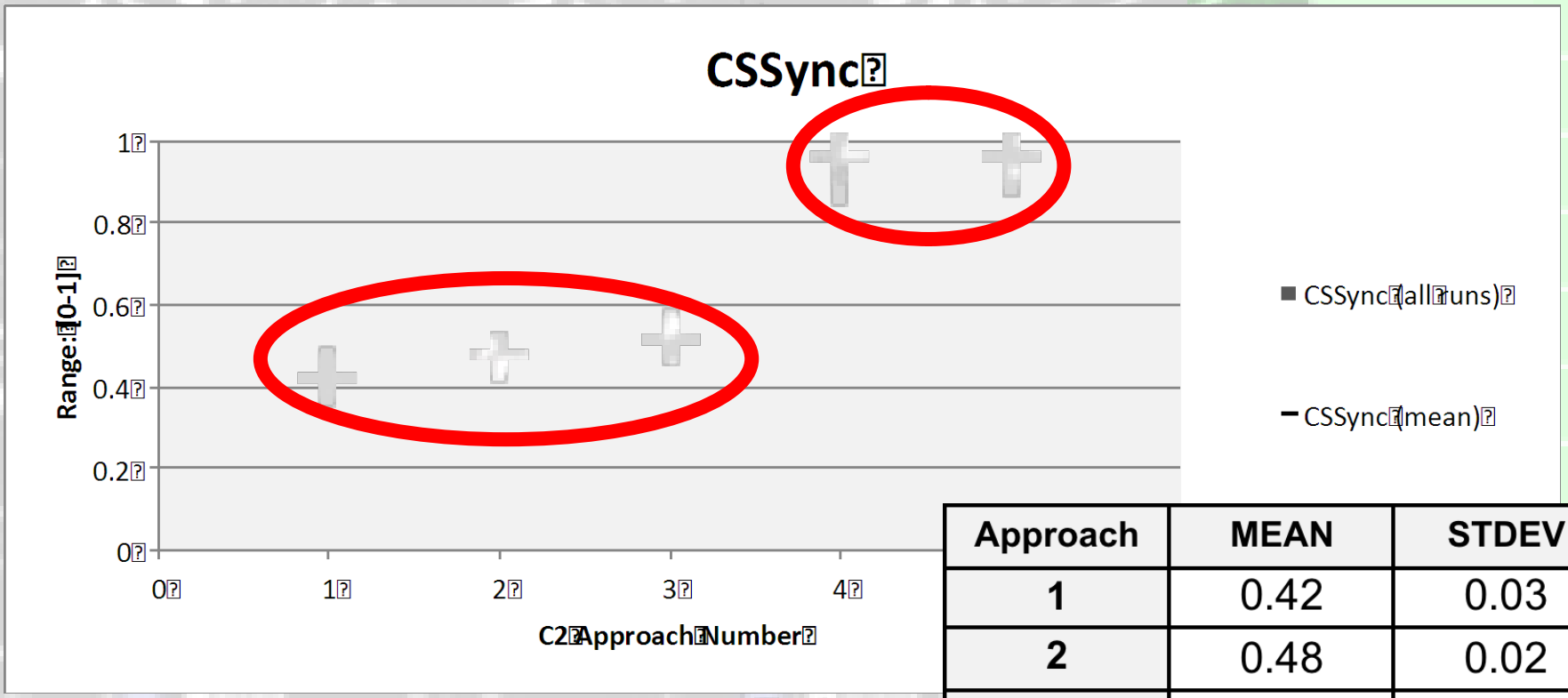
- Cognitive Domain



Level	MEAN	STDEV
1	9.11	2.59
2	11.59	2.28
3	10.19	2.14
4	61.85	7.72
5	61.96	7.27

Analysis

- Cognitive Domain

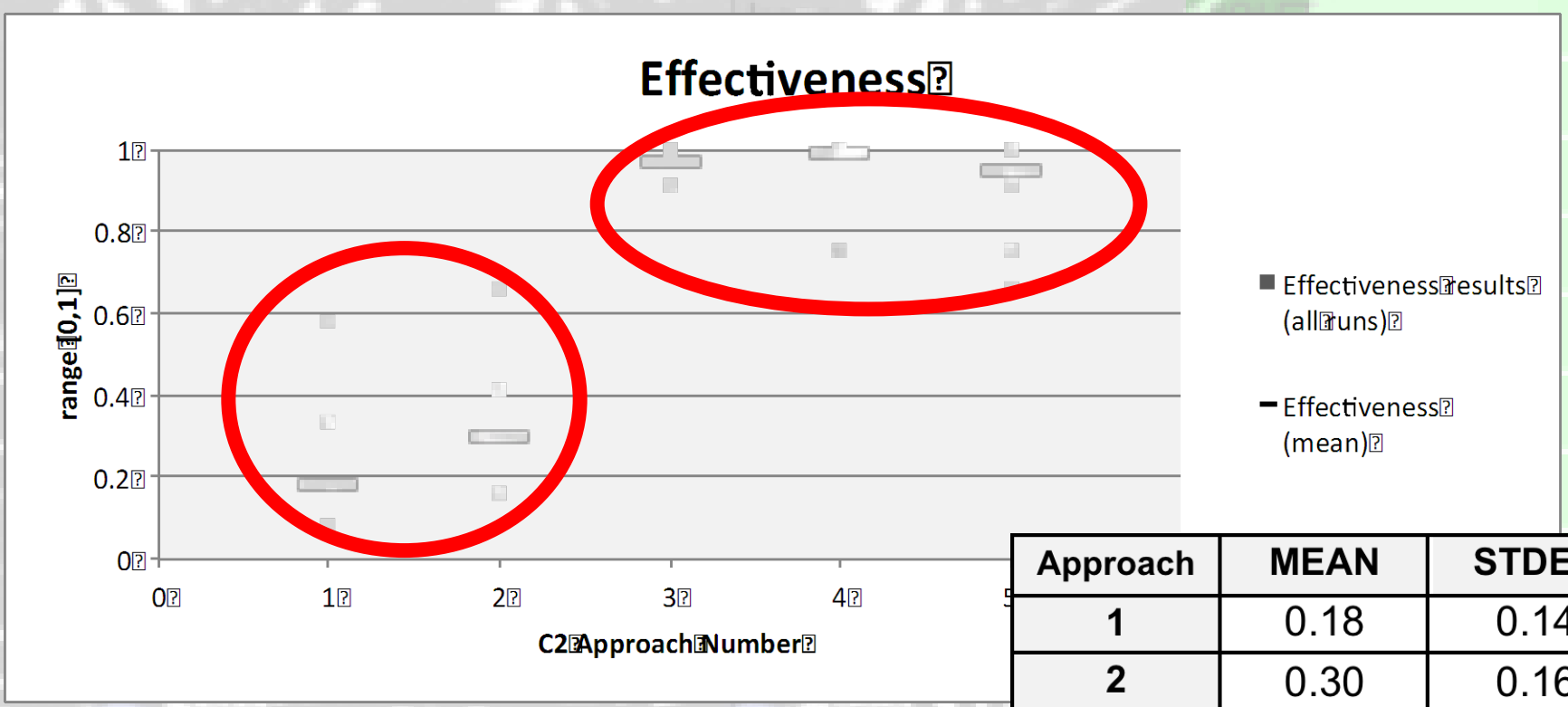


Approach	MEAN	STDEV
1	0.42	0.03
2	0.48	0.02
3	0.52	0.03
4	0.96	0.04
5	0.96	0.04

For info on CSSync See (Manso and Moffat 2011)

Analysis

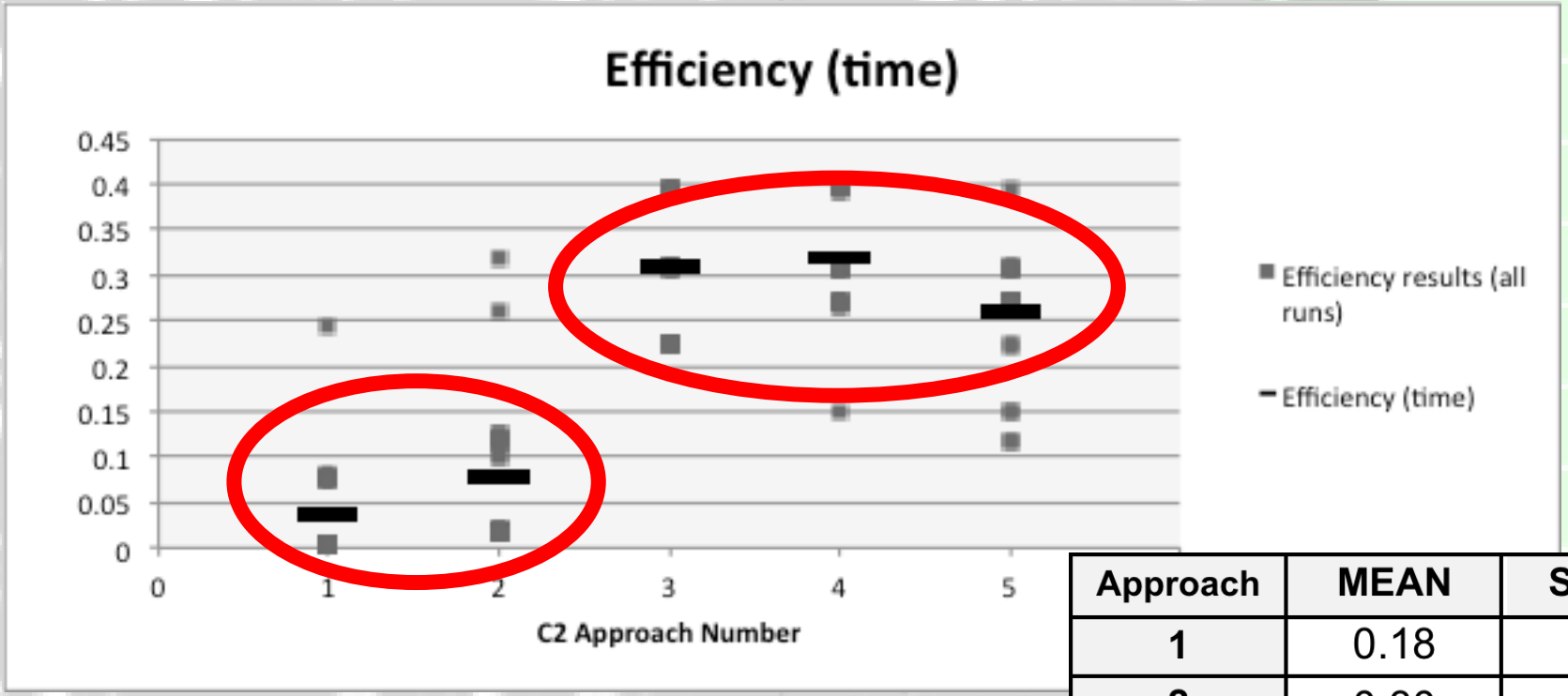
- Effectiveness (approach specific)



Approach	MEAN	STDEV
1	0.18	0.14
2	0.30	0.16
3	0.97	0.04
4	0.99	0.05
5	0.95	0.11

Analysis

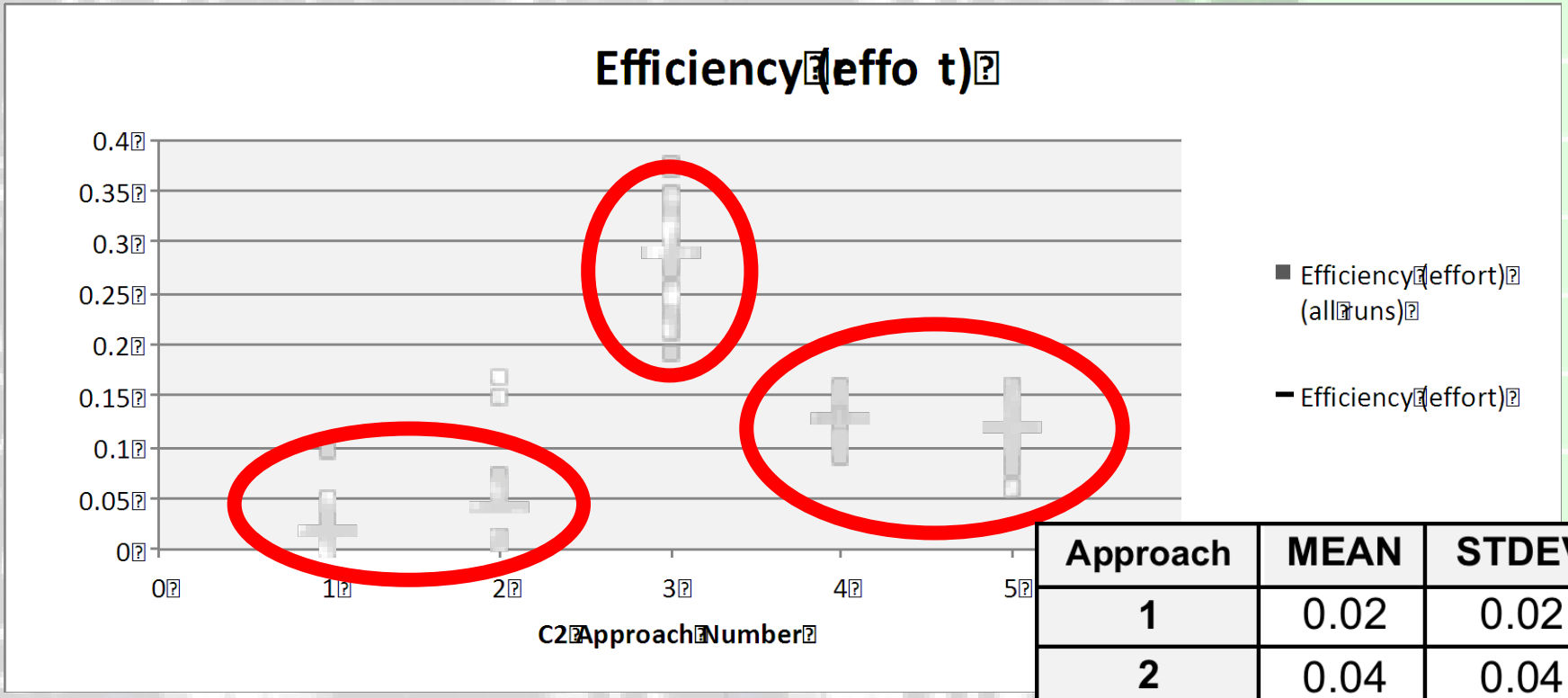
- Efficiency-time (approach specific)



Approach	MEAN	STDEV
1	0.18	0.14
2	0.30	0.16
3	0.97	0.04
4	0.99	0.05
5	0.95	0.11

Analysis

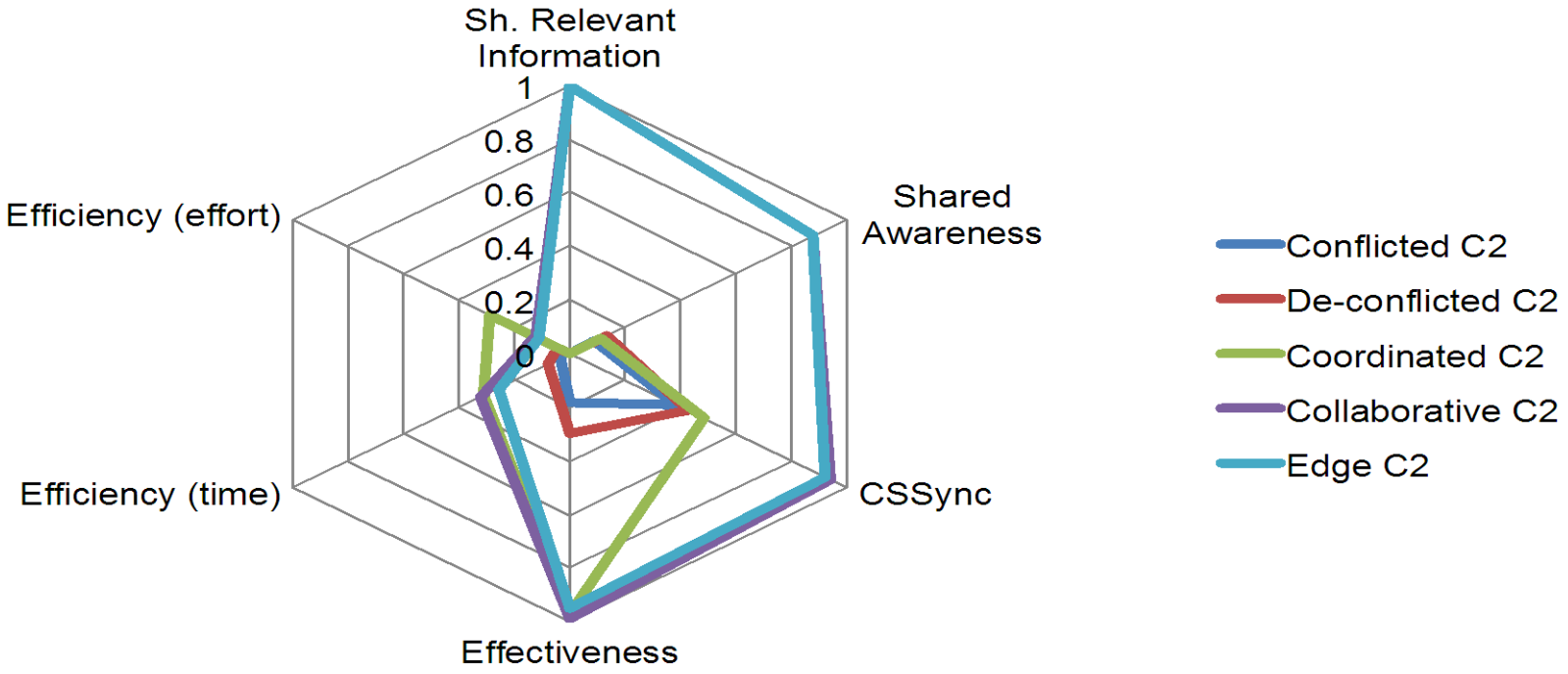
- Efficiency-effort (approach specific)



Approach	MEAN	STDEV
1	0.02	0.02
2	0.04	0.04
3	0.29	0.05
4	0.13	0.02
5	0.12	0.03

Conclusions

- Overall Results



Conclusions

- Overall Results
  - More network-enabled C2 approaches achieve more:
    - **shared information**,
    - **shared awareness** and
    - **self-synchronization**
  - than less network-enabled C2 approaches
  - On **effectiveness** and **efficiency-time** two clusters are formed:
    - Cluster 1 (high scores): COORDINATED, COLLABORATIVE and EDGE
    - Cluster 2 (low scores): CONFLICTED and DE-CONFLICTED
  - On **efficiency-effort** three clusters are formed:
    - Cluster 1 (high scores): COORDINATED
    - Cluster 2 (med scores): COLLABORATIVE and EDGE
    - Cluster 3 (low scores): CONFLICTED and DE-CONFLICTED

Conclusions

- Overall Results
  - Agents *behave* better than humans
  - Agents don’t differentiate according to role
  - The key condition for success is having all information available (not true for humans)
  - Collaborative and Edge yield similar results with agents (as opposed to human runs)
- Recommendations:
  - Extend ELICIT (more dynamics, more uncertainty, decision-making and actions)
  - Further enlarge human-runs dataset

Acknowledgements

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Thank You for your attention !

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