Development of Robust Traceability Benchmarks

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Traceability links

- Inter-relationships between artifacts

Links	Correct	Incorrect
Captured	True positive (True links)	False positive (Incorrect links)
Fail to be captured	False negative (Missing links)	True negative

What is a Traceability Benchmark?

- A standard test or set of tests employed to compare the performance of traceability recovery techniques [1].
- Four components
  - **Dataset**
  - **Tasks**
  - **Answer sets**
  - **Measures**

Barriers

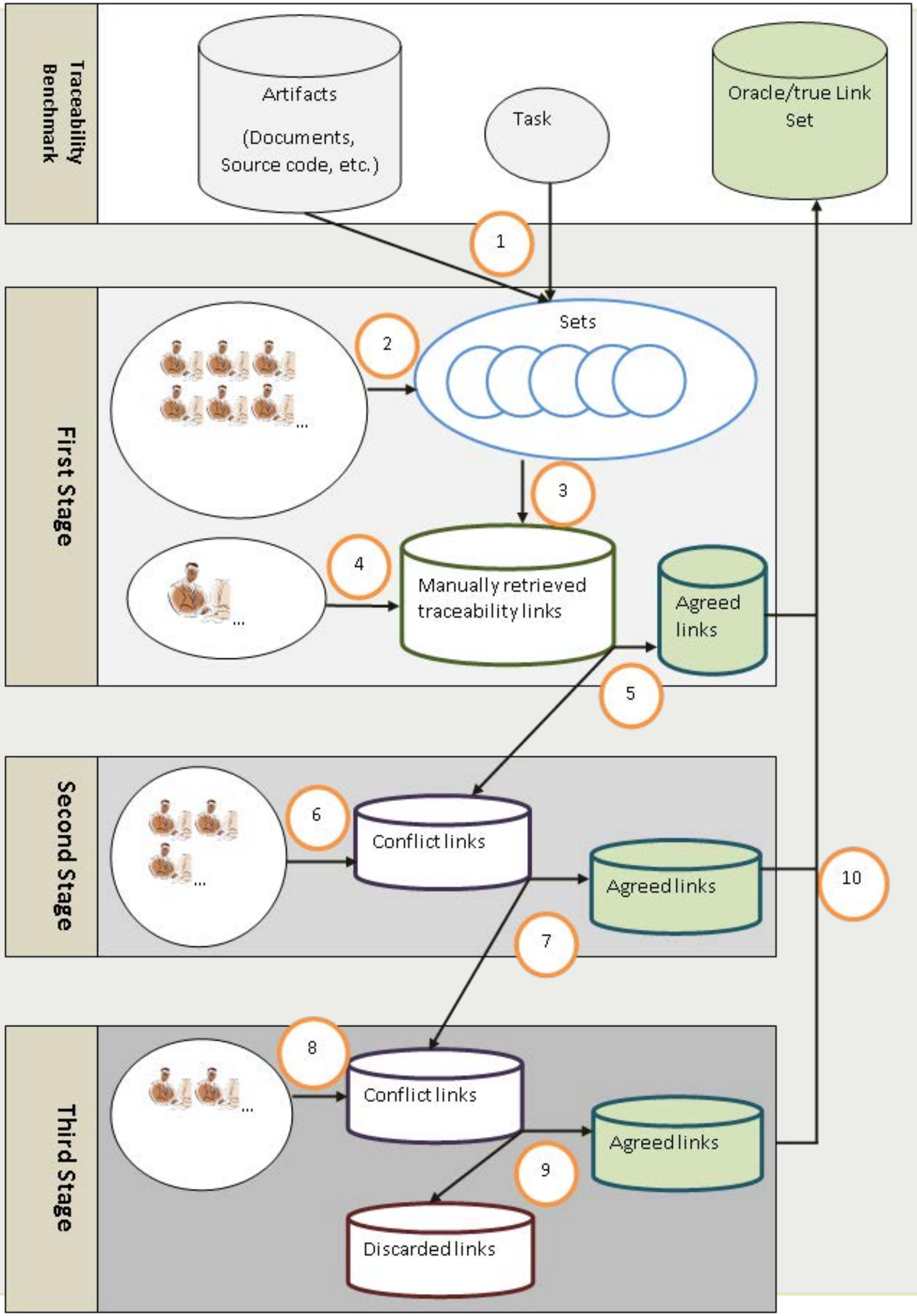
- The lack of publicly available benchmarks
- The diversity of traceability issues
- The difficulty of manually building benchmarks

Issues

- Three key issues:
  - how to find an appropriate dataset
  - how to manually identify correct links
  - how to verify links are correct or not.
- No guidelines to assist researchers in developing traceability benchmarks.

Our approach

- Five steps to build a benchmark
  - Task identification
  - Artifact selection
  - Project selection
  - True link set development
  - Evaluation metrics
    - Precision, recall, F-measure



Traceability Benchmark
Artifacts
(Documents, Source code, etc.)
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First Stage
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Agreed links
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Second Stage
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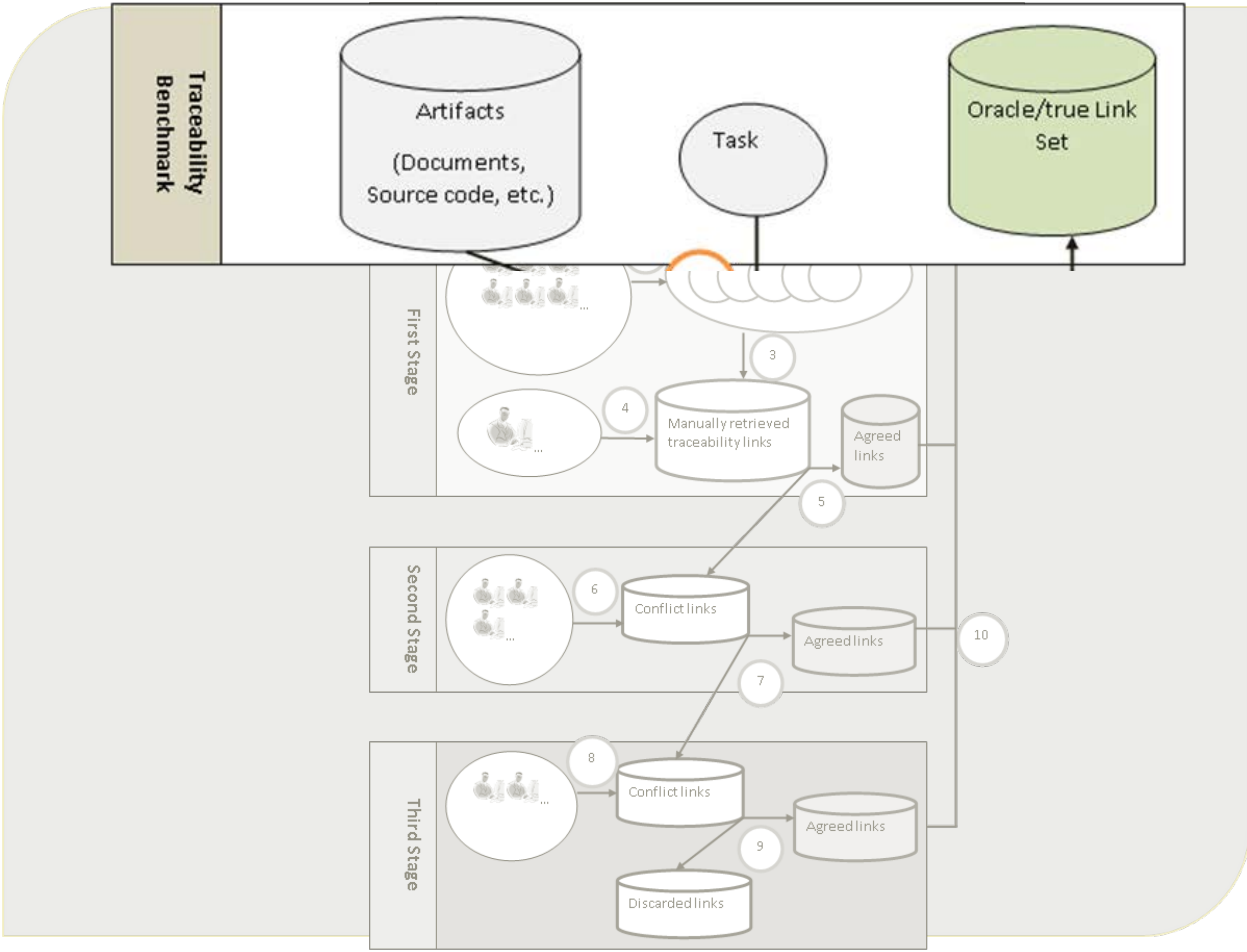

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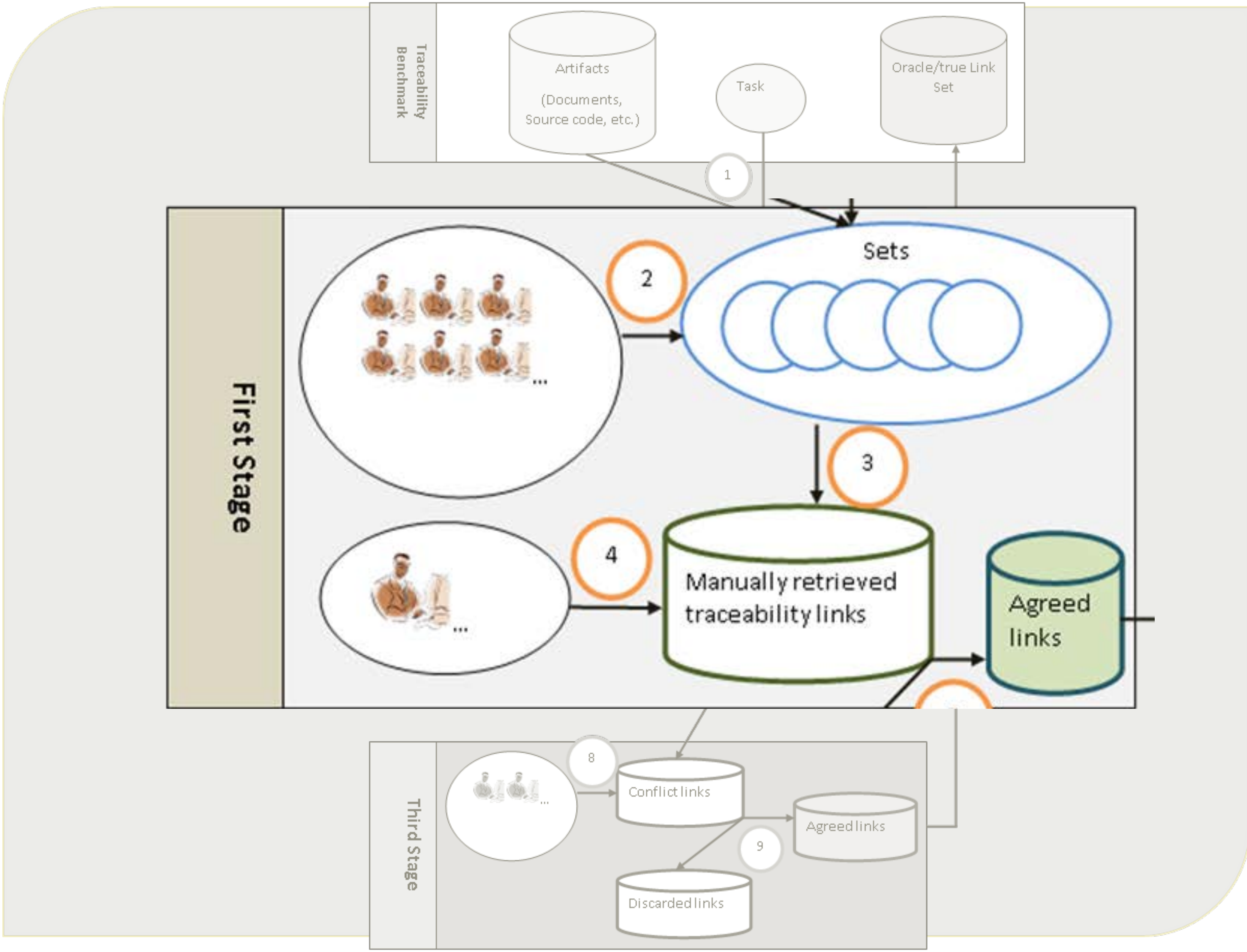

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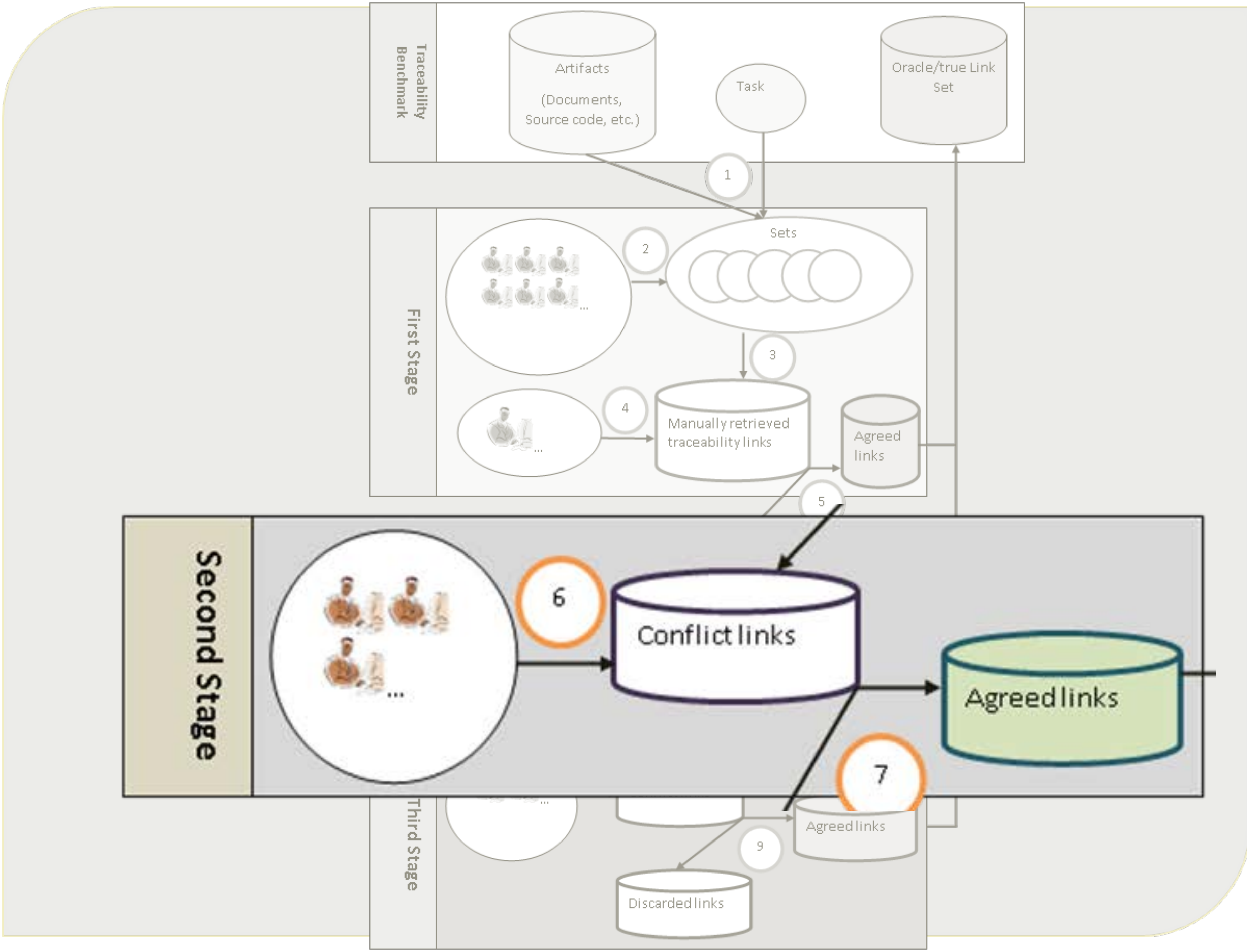
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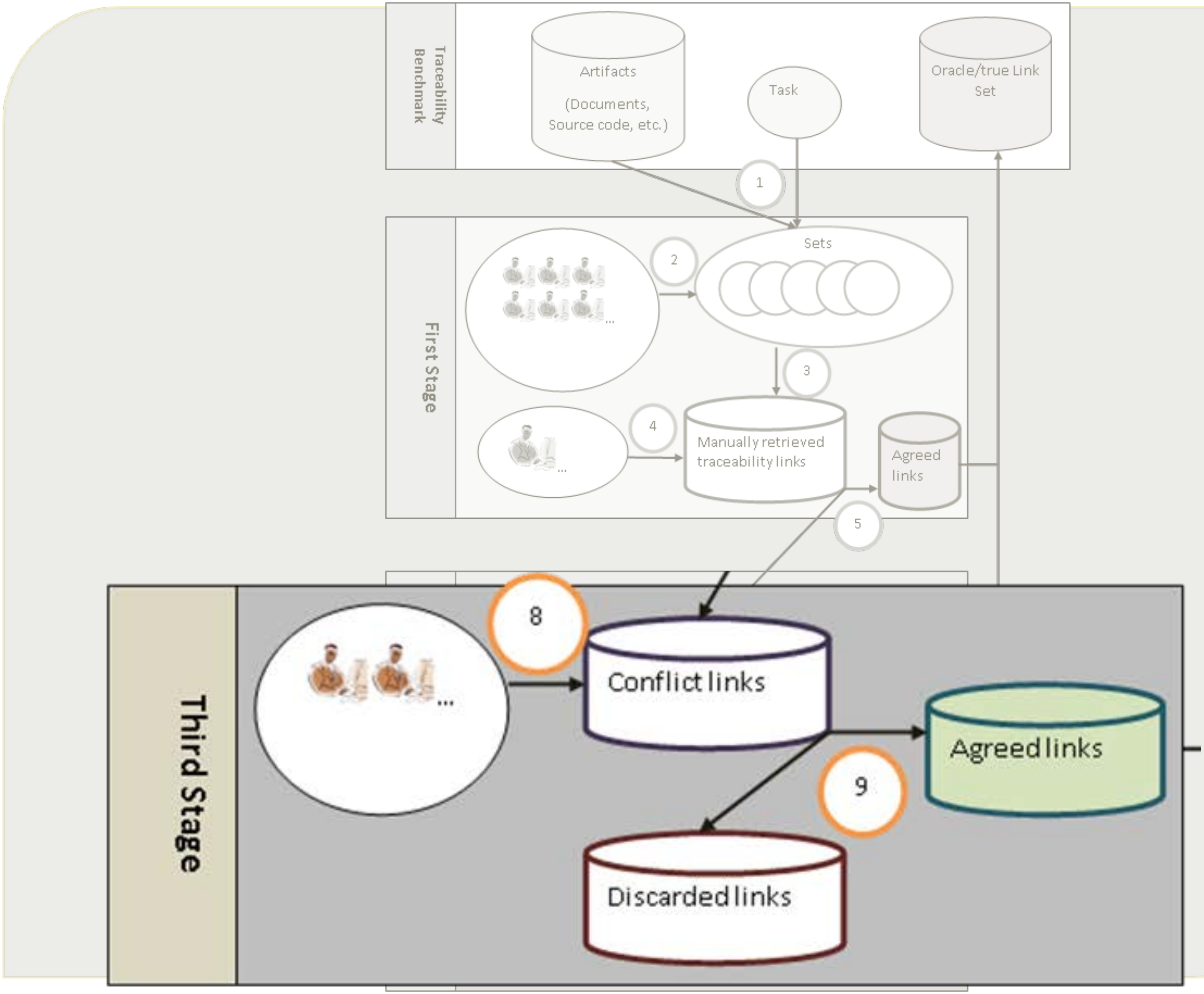

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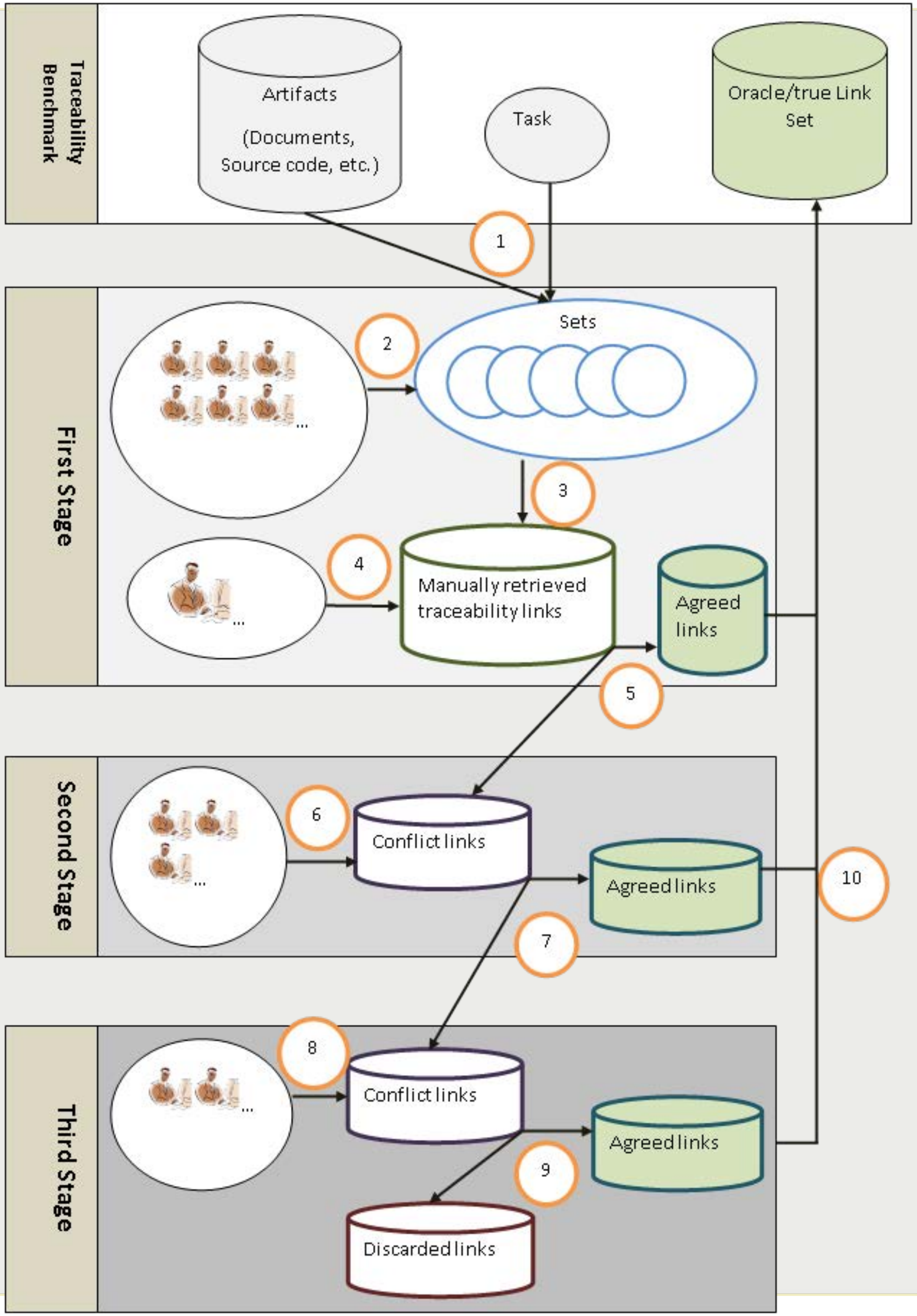

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Probability of errors

- Assumptions:
  - Errors are dependent on the type of participant
  - Links are independent
  - Errors made on links are independent
- Formula:

$$\Pr[E] = \frac{\sum_{i=1}^{k} (n_i \times \Pr[e_i])}{N}$$

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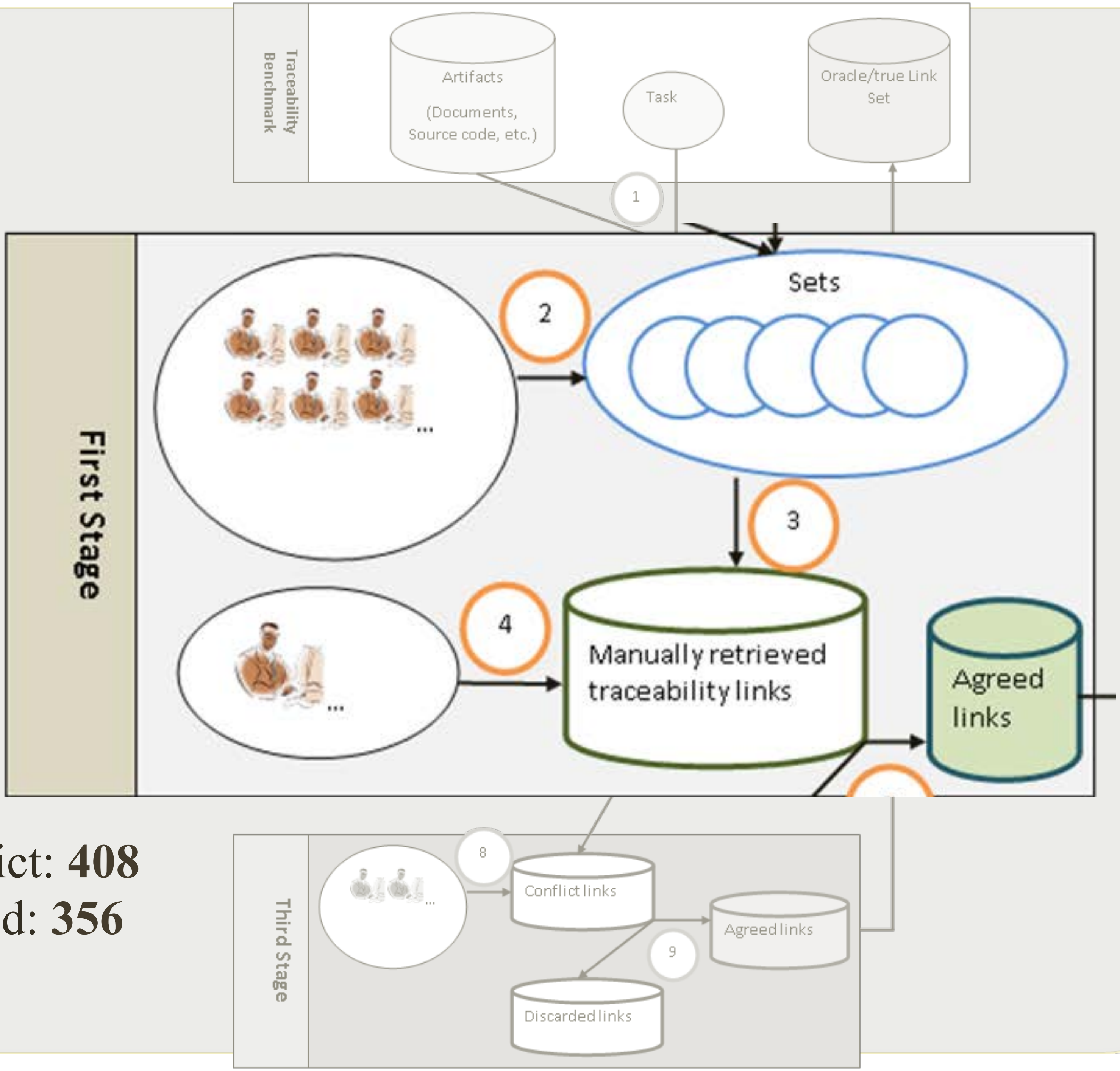
$$P(x) = \frac{n!}{(n-x)!x!} \times p^x \times q^{n-x}$$

Case study

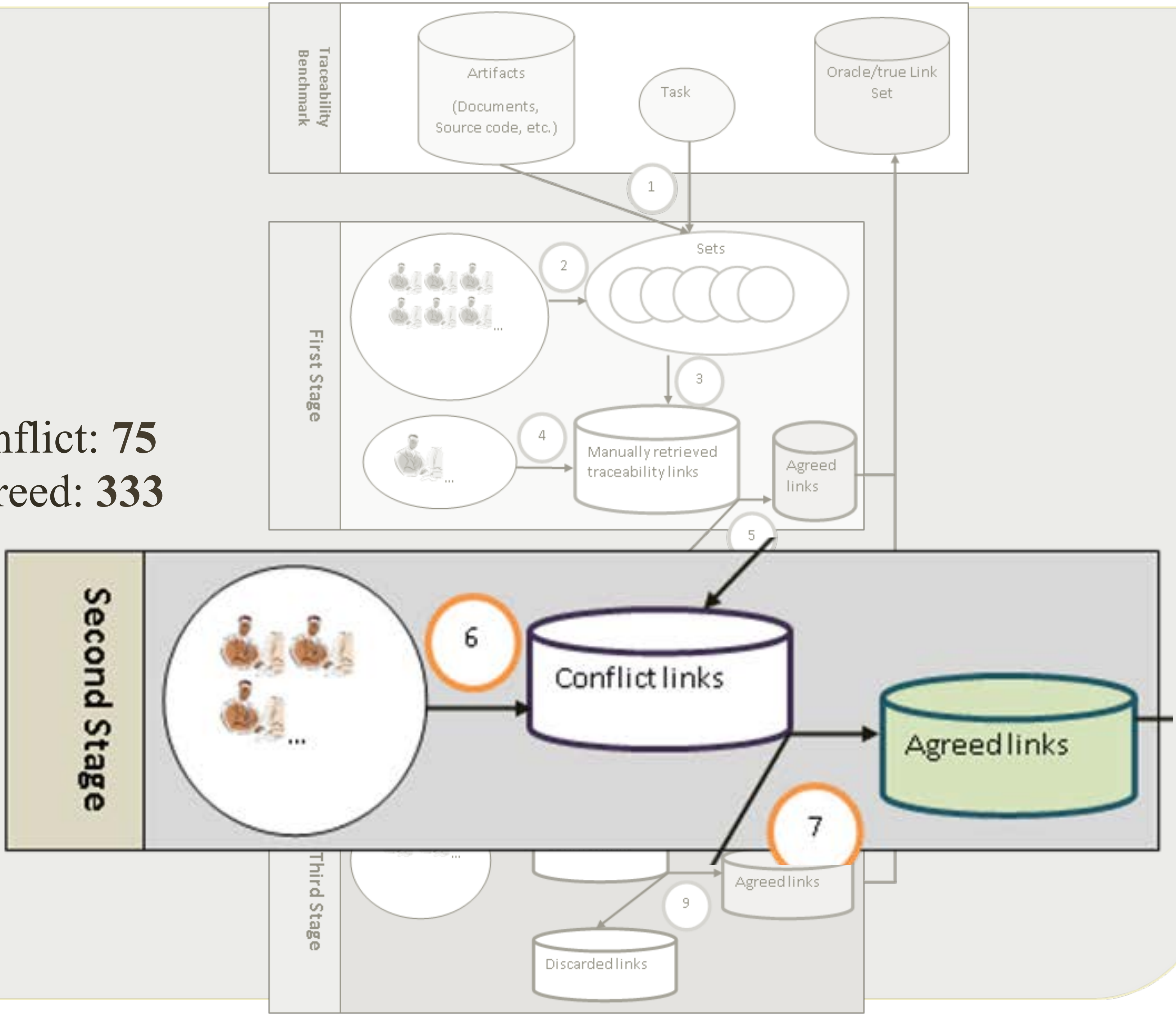
JDK 1.5		**#classes / sections**
Java packages	java.awt, javax.naming, and javax.print packages	249
PDF files	***JPS_PDF.pdf***: Java™ Print Service API User Guide	68
	dnd1.pdf: Drag and Drop subsystem for the Java Foundation Classes	41
	jndispi.pdf: Java Naming and Directory Interface™ Service Provider Interface(JNDI SPI)	73
	Total sections:	182



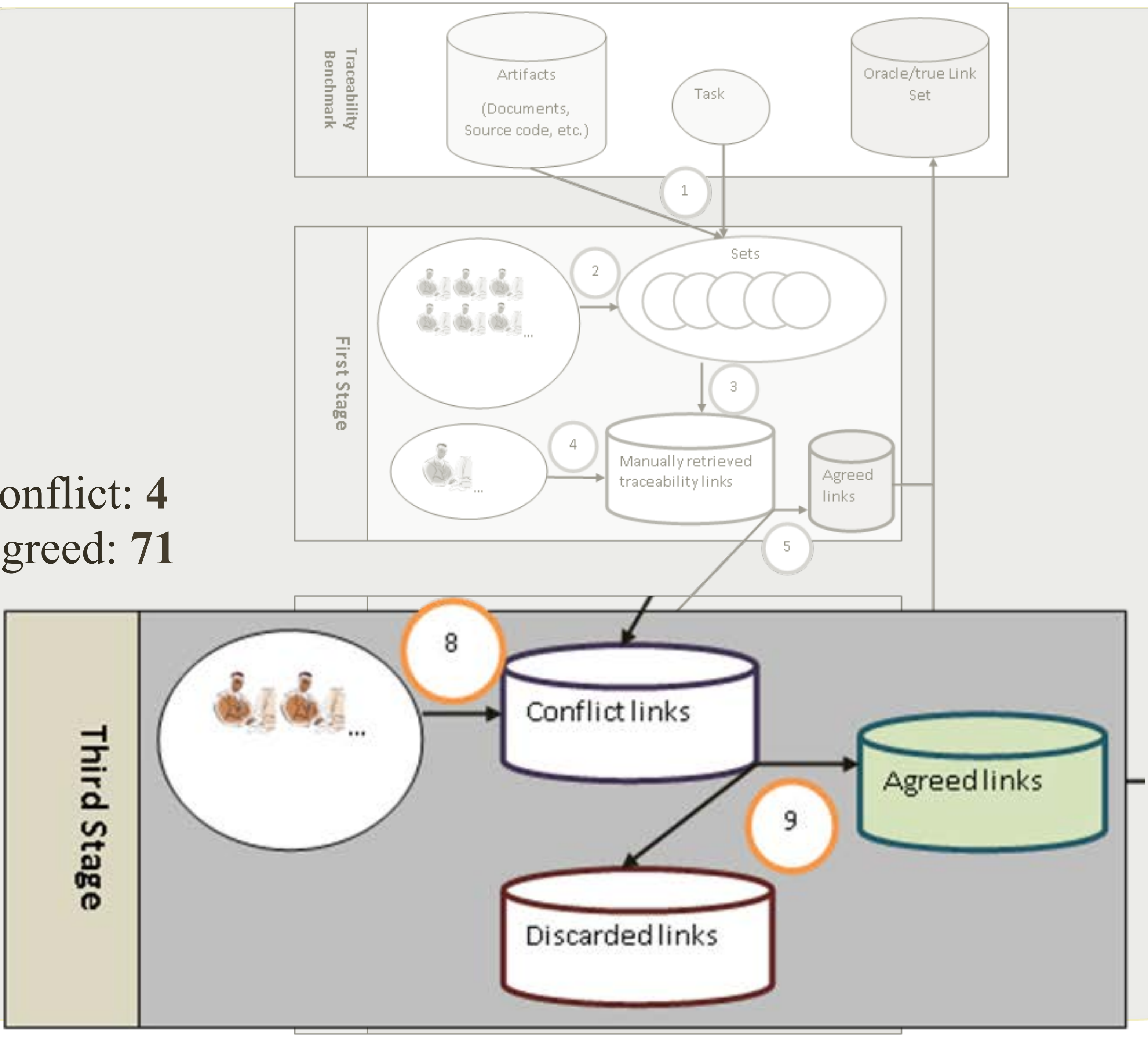
Conflict: **408**

Agreed: **356**

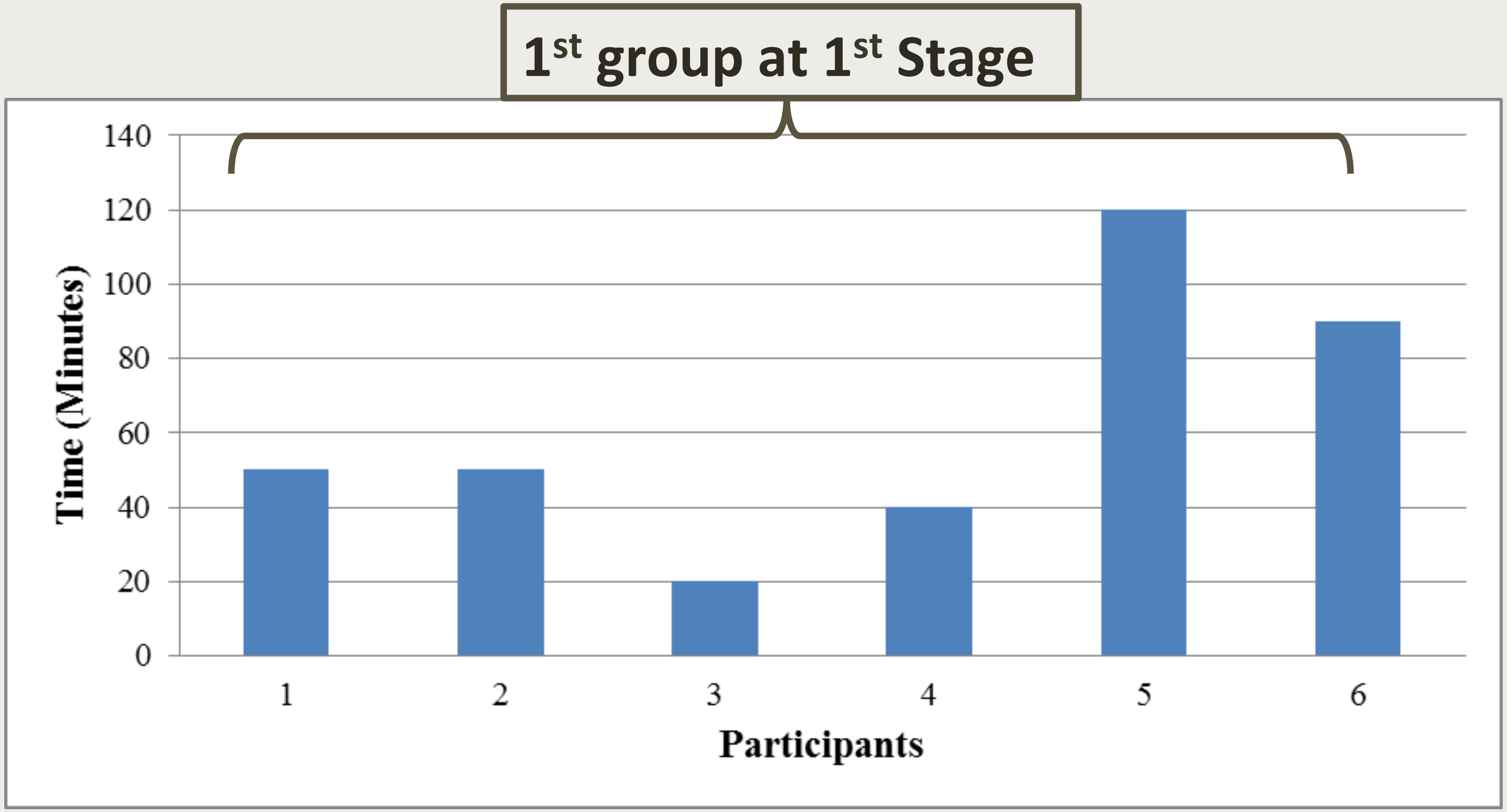
Conflict: **75**
Agreed: **333**



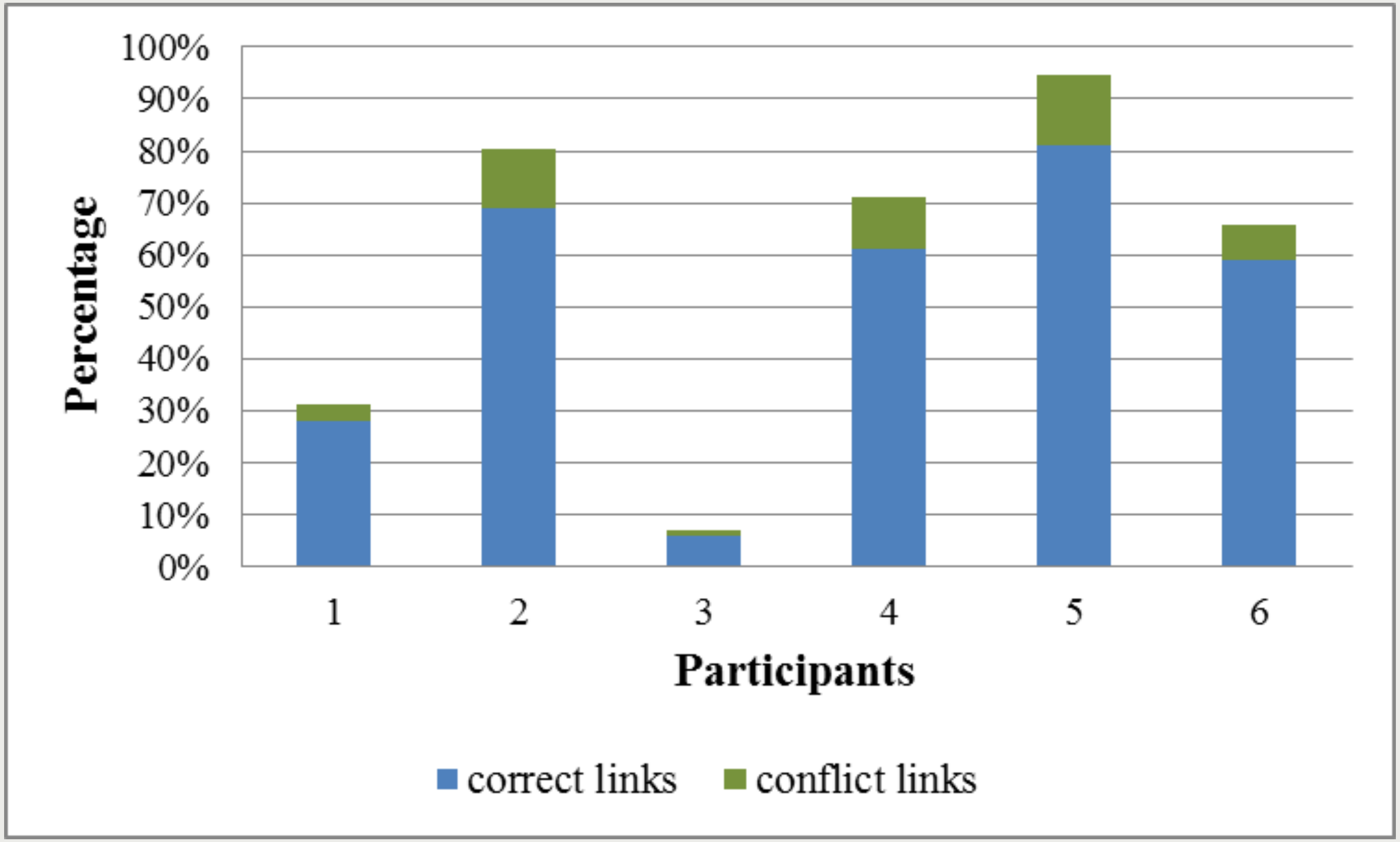
Conflict: **4**
Agreed: **71**



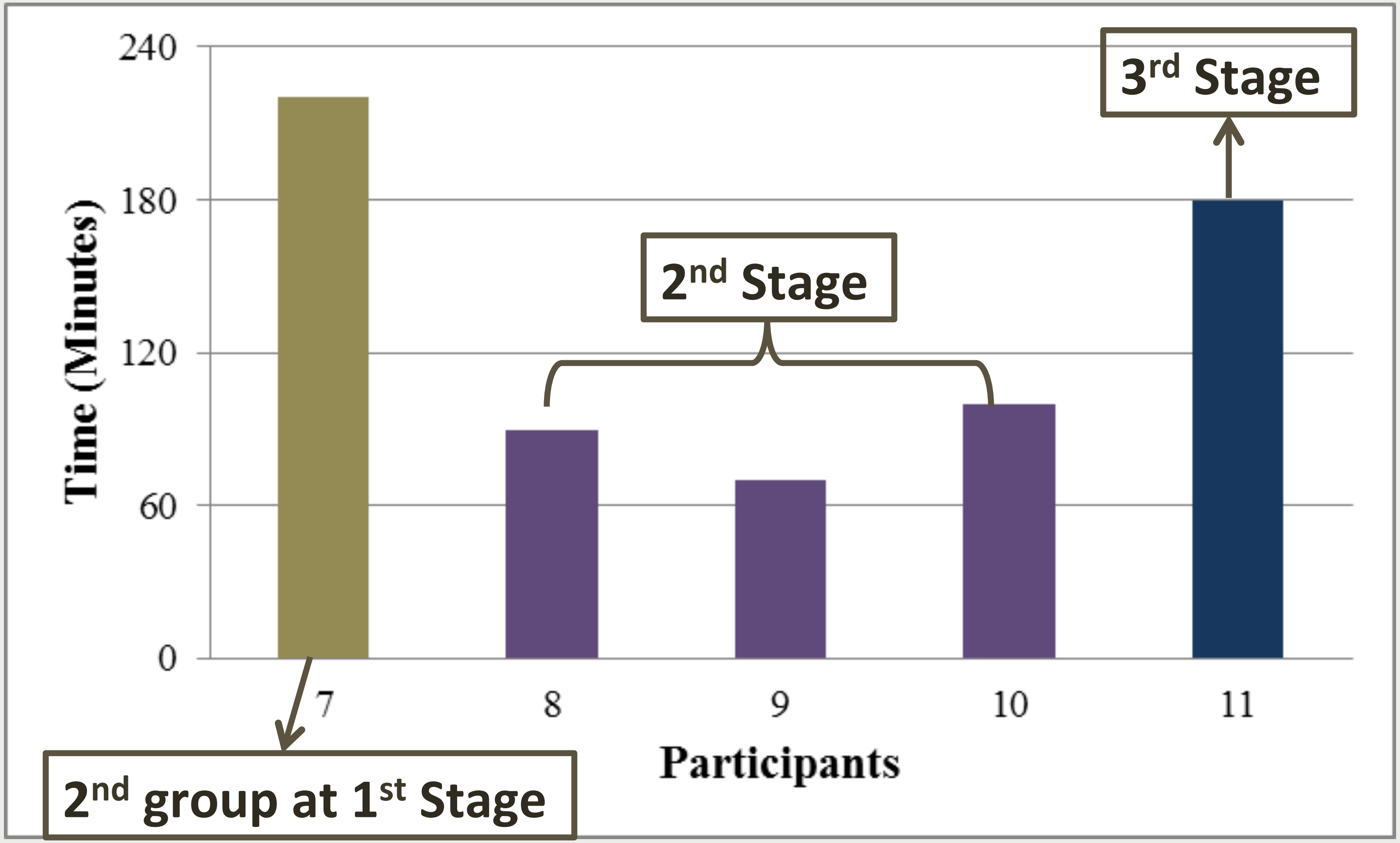
Time taken by the first six participants at the first stage



Links captured by the first six participants



Time taken by the rest of the participants in verifying links



Stage	Participant	Retrieved Links (R)	Conflict Links (C)	Agreed Links ($n=R-C$)	Example Error Probability for Participant (p)	$Pr(x_j)$ for $x_j \geq n$ * 10% (round to the nearest integer)
1st stage	1	10	1	9	0.2	0.8657823
	2	84	12	72	0.2	0.9940038
	3	18	2	16	0.2	0.8592625
	4	35	5	30	0.2	0.955821
	5	145	21	124	0.2	0.9990852
	6	117	12	105	0.2	0.9969877
	7	764	408	356	0.1	0.497614
	$\sum_{j=1}^{m_1} \Pr(x_j) \Big/ m_1 = \sum_{j=1}^{7} \Pr(x_j) \Big/ 7 = 0.881222357$					
	$Pr(y_1) = 0.0225$ for $y_1 \geq 2$, where $n=2$, $p=(0.2+0.1)/2=0.15$					
2nd stage	8	272	53	219	0.2	0.9999765
	9	272	123	149	0.2	0.9996381
	10	272	87	185	0.2	0.9998751
	$\sum_{j=1}^{m_2} \Pr(x_j) \Big/ m_2 = \sum_{j=1}^{3} \Pr(x_j) \Big/ 3 = 0.9998299$					
	$Pr(y_2) = 0.04$ for $y_2 \geq 2$, where $n=2$, $p=(0.2+0.2)/2=0.2$					
3rd stage	11	75	4	71	0.05	0.0641971
	$\sum_{j=1}^{m_3} \Pr(x_j) \Big/ m_3 = \sum_{j=1}^{1} \Pr(x_j) \Big/ 1 = 0.0641971$					
	$Pr(y_3) = 0.0266119$ for $y_3 \geq 3$, where $n=5$, $p=(0.2+0.1+0.2+0.2+0.05)/5=0.15$					

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	6	117	12	105	0.2	69877
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2nd stage	8	272	53	219	0.2	99765
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$$\Pr[e_i] = \left(\sum_{j=1}^{m_i} \Pr(x_j) \Big/ m_i\right) \times \Pr(y_i)$$

$$\Pr[E] = \frac{\Pr[e_1]\times n_1 + \Pr[e_2]\times n_2 + \Pr[e_3]\times n_3}{N}$$

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						Pr(y_3) = 0.0266119 for $y_3 \geq 3$, where *n*=5, *p*=(0.2+0.1+0.2+0.2+0.05)/5=0.15

$$\Pr[E] = \frac{\Pr[e_1]\times n_1 + \Pr[e_2]\times n_2 + \Pr[e_3]\times n_3}{N}$$

***Pr[E]*=0.027** for *E*>=*N**10%

- N = 760
- n_1 = 356, n_2 = 333, and n_3 = 71

Stage	Participant	Retrieved Links (*R*)	Conflict Links (*C*)	Agreed Links (*n*=*R*-*C*)	Example Error Probability for Participant (*p*)	$Pr(x_j)$ for $x_j \geq n$ * 10% (round to the nearest integer)
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	[illegible] *p*=(0.2+0.1)/2=0.15					
2nd stage	8	[illegible]	[illegible]	[illegible]	[illegible]	0.9999765
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	10	[illegible]	[illegible]	[illegible]	[illegible]	0.9998751
	[illegible] $(x_j) \Big/ 3 = 0.9998299$					
	Pr(y₂) = 0.04 for *y₂*≥2, where *n*=2, *p*=(0.2+0.2)/2=0.2					
3rd stage	11	75	4	71	0.05	0.0641971
	$\sum_{j=1}^{m_3} \Pr(x_j) \Big/ m_3 = \sum_{j=1}^{1} \Pr(x_j) \Big/ 1 = 0.0641971$					
	$Pr(y_3) = 0.0266119$ for $y_3 \geq 3$, where *n*=5, *p*=(0.2+0.1+0.2+0.2+0.05)/5=0.15					

Actual error rates for participants

Stage	Participant	Retrieved Links (*R*)	Incorrect Links (*W*)	Actual Error Probability (*p*=*W*/*R*)
1st stage	1	10	1	0.1
	2	84	5	0.05952
	3	18	1	0.05556
	4	35	3	0.08571
	5	145	6	0.04138
	6	117	6	0.05128
	7	***764***	***31***	***0.04058***
2nd stage	8	272	3	0.01103
	9	272	8	0.02941
	10	272	6	0.02206
3rd stage	***11***	***75***	***2***	***0.02667***

$$Pr[E] = 0.0012 \text{ for } E \geq N*5\%$$

Cost-quality tradeoffs

- Workload allocated to each participant
- Number of participants verifying a link
- Knowledge of the traced project of each participant

Problems

- The difficulty of determining whether two elements are related.
- How much workload is suitable for a participant to undertake?
- The difficulty of recruitment.
- The scalability of benchmarks.

Threats to validity

- False positive links may be included.
- Some links may be harder to identify.
- True links may fail to be included.
- The case we used is a small fraction of the JDK1.5 system.
- May show different probability error results for different systems and participants.

Future work

- Extend the JDK1.5 benchmark
- Explore other probability distributions

Summary

- Five steps to build a benchmark
- Rigorous identification and verification strategies
- A formula to compute the probability error
- JDK1.5 benchmark is available from:
  - http://tinyurl.com/7l3ohe4.

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