ADTRIBUTOR: REVENUE DEBUGGING IN ADVERTISING SYSTEMS

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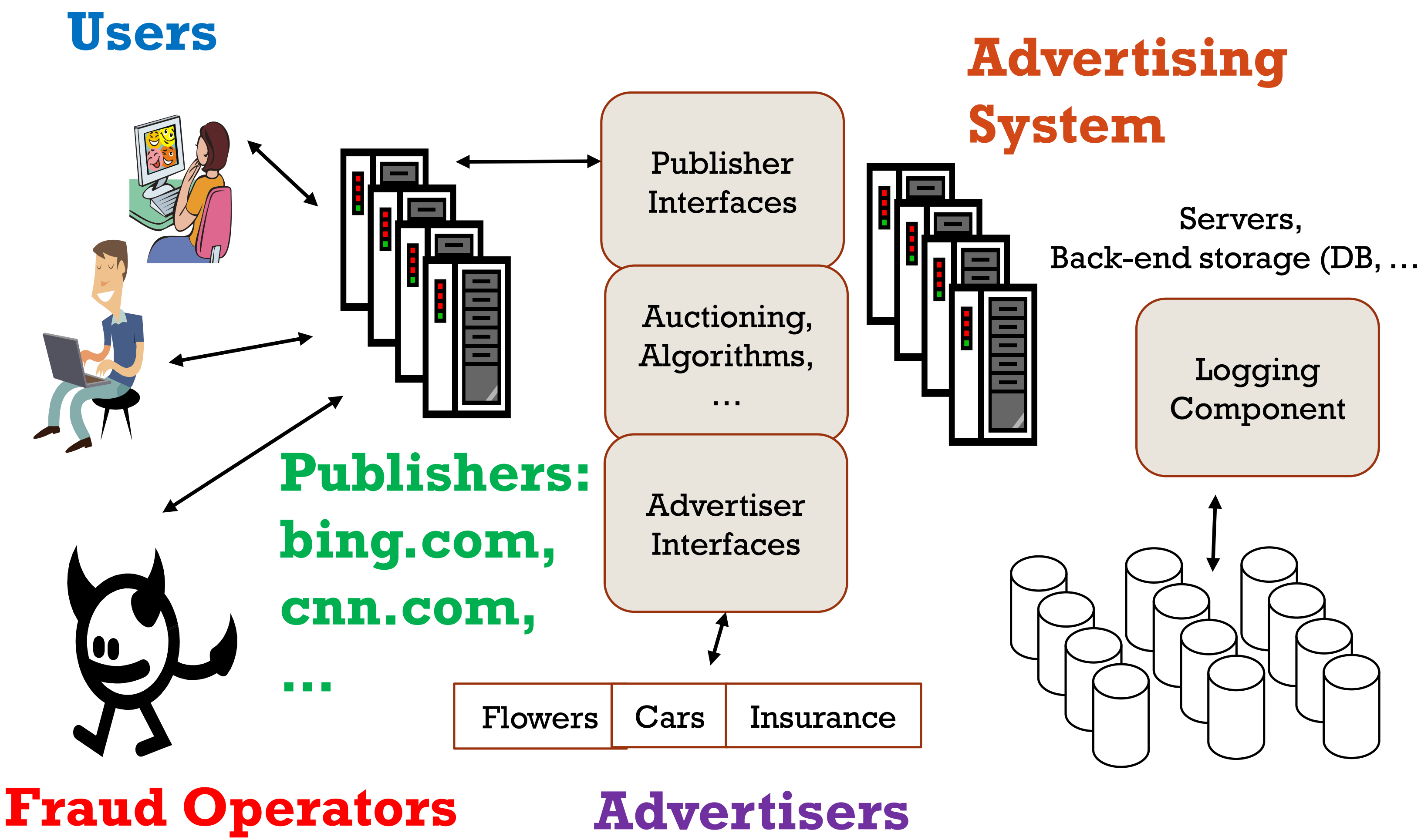
MICROSOFT

ADVERTISING SYSTEMS ARE COMPLEX



REVENUE DEBUGGING IN ADVERTISING SYSTEMS

Why is Revenue/Revenue-per-search down *anomalously*?

Measures

Derived Measures

Anomaly Detection Problem ⇄ **Root Cause Analysis**

Dimensions

Values

- **Datacenter** in **Dublin** had latency issues that resulted in fewer ads being served
- **Buckets 18, 23, and 24** were using a new algorithm for ad relevance that wasn't working as expected.
  - Buckets: experimental trials with different algorithms
- The papal election was in progress, and users were searching for mainly non-monetizable **queries** such as **"Pope"**

CONTRIBUTIONS

1. **Novel algorithm for root cause analysis in Ad Systems**
   - Uses explanatory power, succinctness and surprise

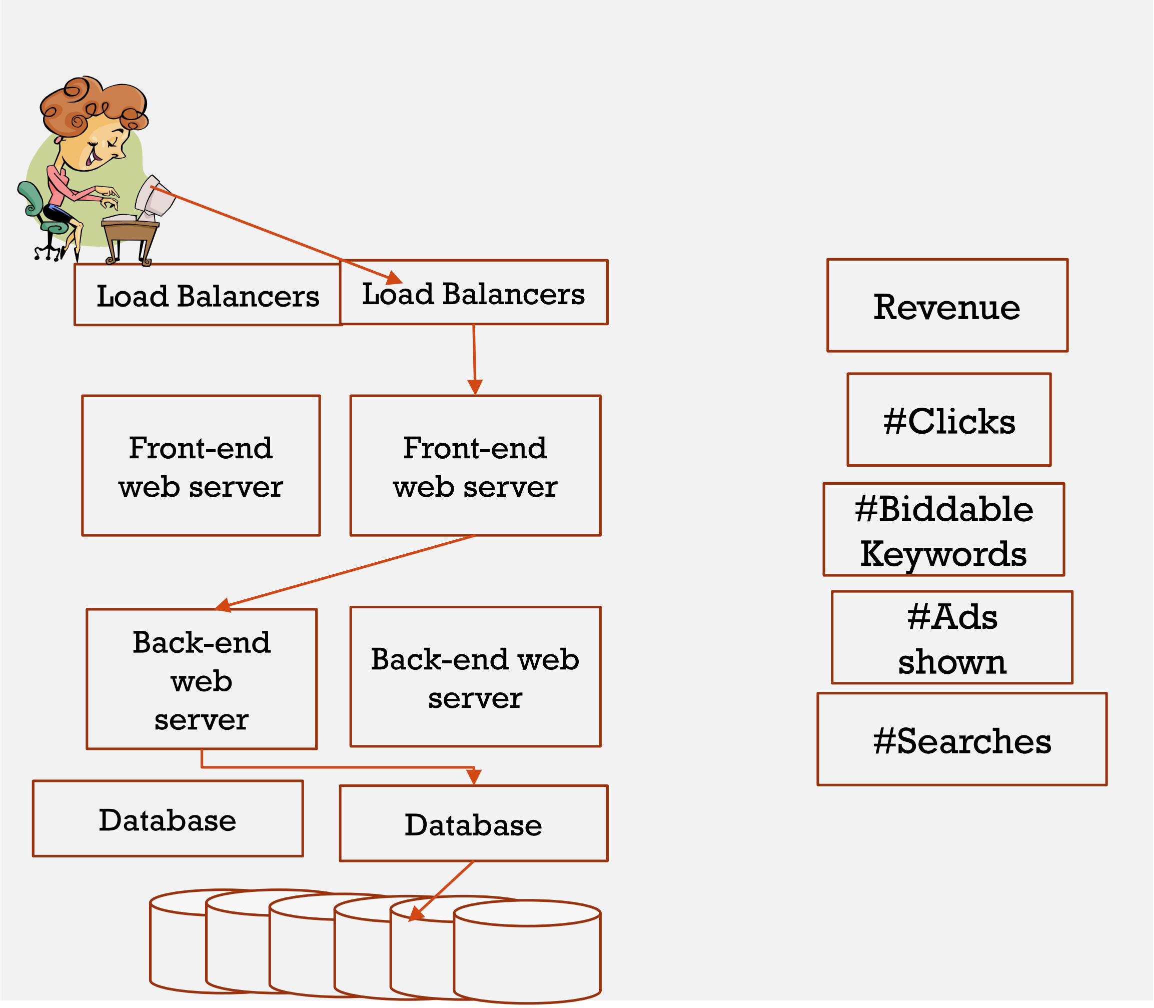
2. **Attribution for derived measures**
   - E.g., attribute an element's contribution to revenue-per-search (revenue/# searches)

3. **Adtributor Tool**
   - 95+% accuracy in identifying root causes in Ad Systems
   - Saves 1+ hour on average of manual troubleshooter time

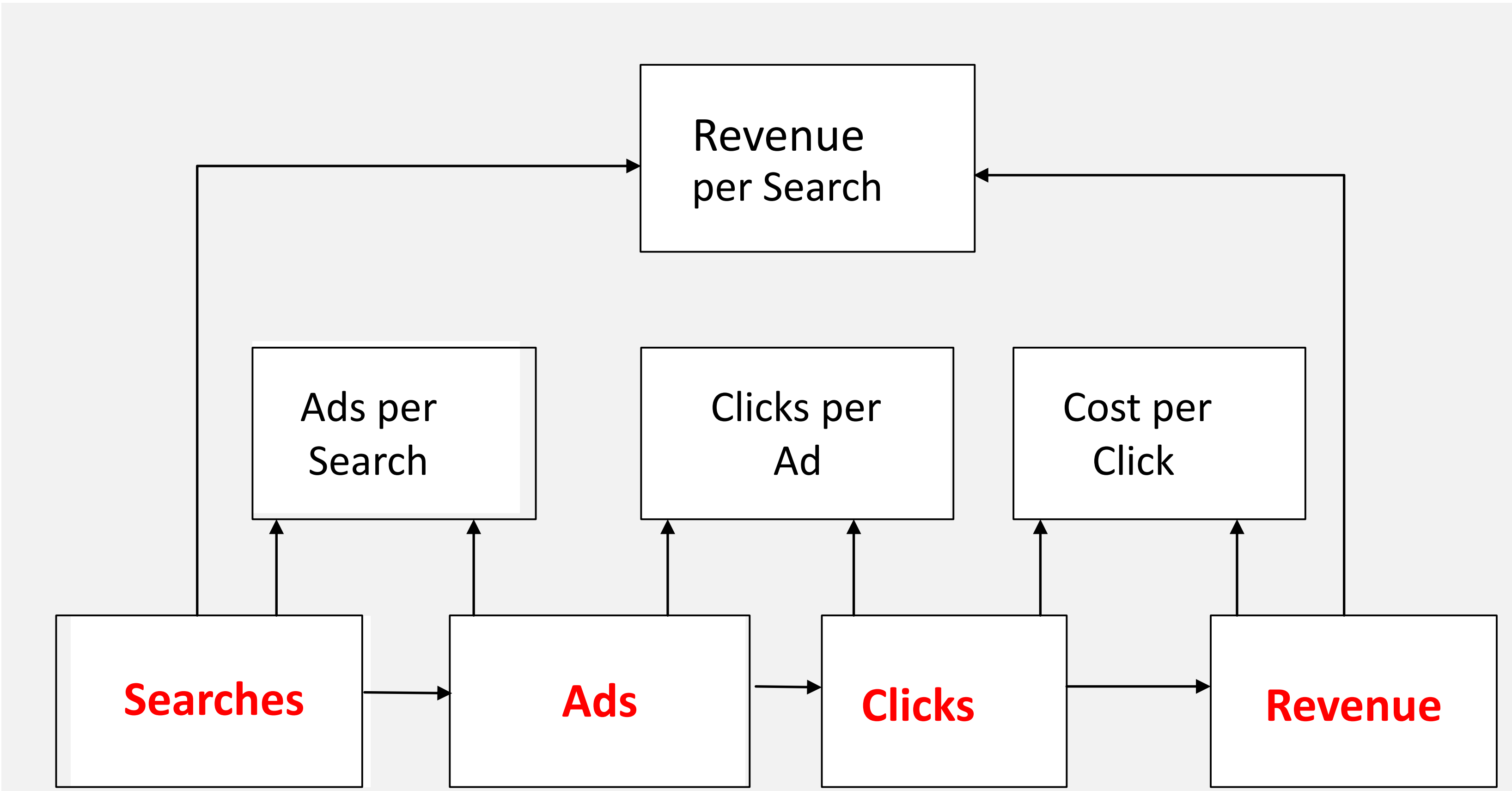
OUTLINE

- Characteristics of Ad systems
- Root cause analysis
- Attribution for derived measures
- Adtributor Demo
- Evaluation

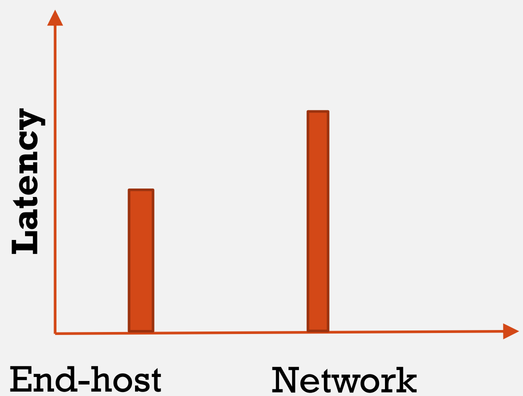
CHARACTERISTIC I: AGGREGATE ANALYSIS



CHARACTERISTIC II: FUNDAMENTAL AND DERIVED MEASURES



CHARACTERISTIC III: MULTI DIMENSIONAL ANALYSIS



System Component Isolation

Publishers

Publishers, Buckets, Advertisers, System Components,…

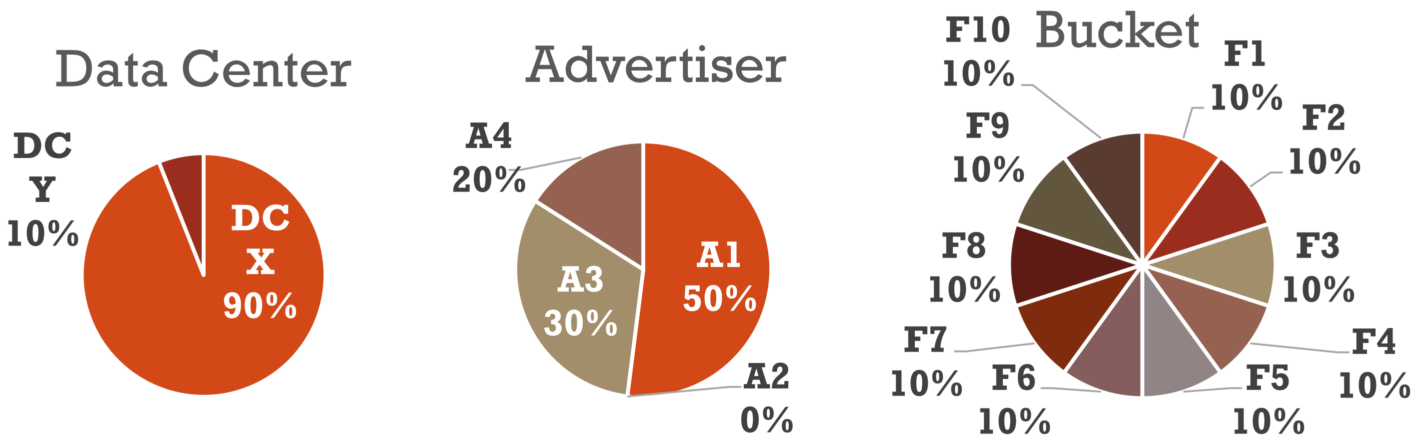
ROOT CAUSE ANALYSIS

- Example
  - Expected Revenue: $100, Actual Revenue: $80
  - Revenue down by 20% → anomaly!

- Potential root causes
  - One data center had $18 less revenue than forecasted
  - Three advertisers spent $20 less than forecasted
  - 10 buckets resulted in $20 less revenue than forecasted

➢ Should we attribute root cause to dimension data center, advertiser or bucket? Which values?

EXPLANATORY POWER AND SUCCINCTNESS



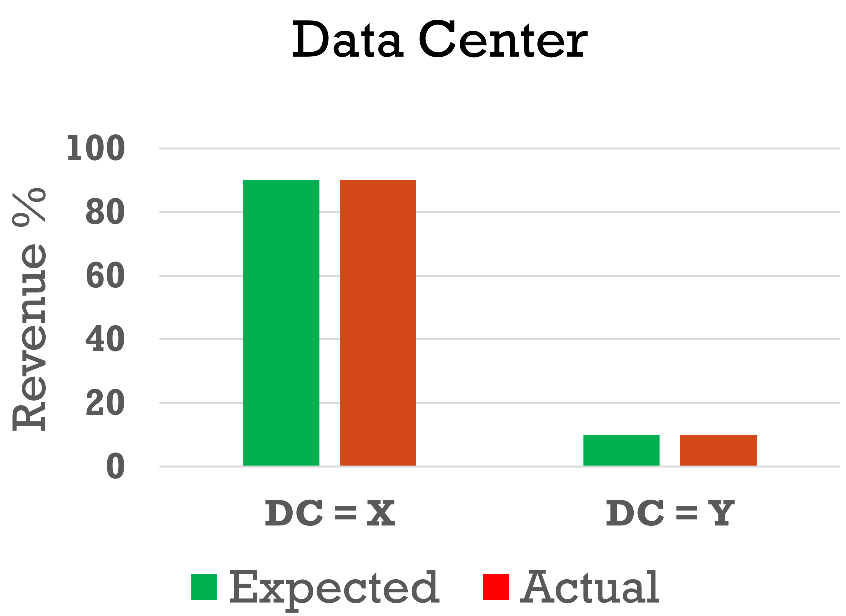
Pie charts show contribution to change by dimension-values.

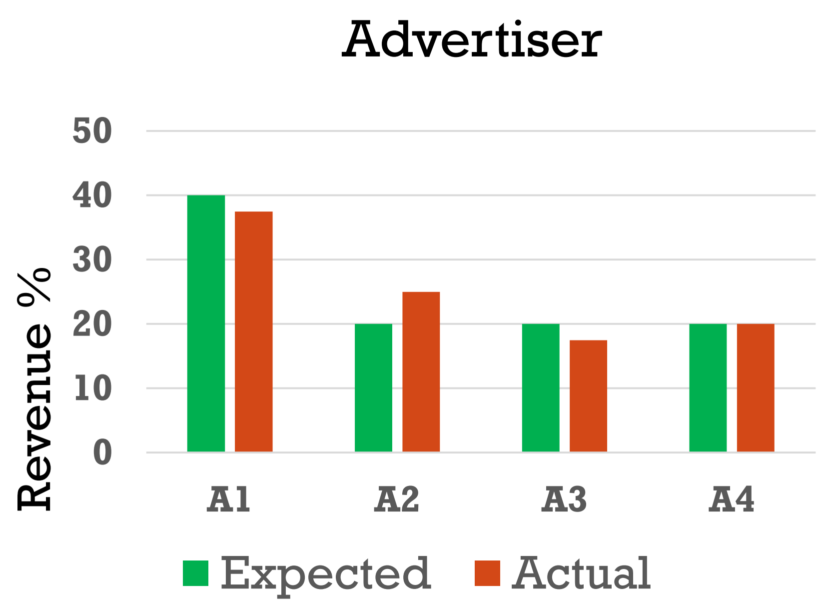
- Explanatory: root cause should explain most of change
- Succinctness: root cause likely to be few elements

➢ **DataCenter == X**

➢ **Advertiser == A1 OR Advertiser == A3 OR Advertiser == A4**

SURPRISE





- Root cause likely to deviate most from expectation
  - Relative entropy of actual vs expected probability (JS-divergence)

➢ **Advertiser == A1 OR Advertiser == A3 OR Advertiser == A4**

ALGORITHM

- Find the dimension and smallest set of values that maximally explain the anomalous change while also maximizing surprise
- Multi-objective optimization
- Greedy algorithm
  - Smallest set → each value contributes > 10% of change
  - Maximally explains → set should explain > 2/3 of change
  - Maximize surprise

Foreach $m \in M$ // Compute surprise for all measures,
    Foreach $i \in D$ // all dimensions,
        Foreach $j \in E_i$ // all elements for a dimension
            $p = V^e_{ij}(m)/V^e(m)$ // Equation 6
            $q = V^a_{ij}(m)/V^a(m)$ // Equation 7
            $S_{ij}(m) = D_{JS}(p, q)$ // Equation 10
ExplanatorySet = {}
Foreach $i \in D$
    $SortedE$ = E_i.SortDescend($S_{ij}(m)$) //Surprise
    Candidate = {}, Explains = 0, Surprise = 0
    Foreach $j \in SortedE$
        EP = $(V^a_{ij}(m) - V^e_{ij}(m))/(V^a(m) - V^e(m))$
        if (EP $> T_{EEP}$) // Occam's razor
            Candidate.Add += E_{ij}
            Surprise += $S_{ij}(m)$, Explains += EP
        if (Explains $> T_{EP}$) // explanatory power
            Candidate.Surprise = Surprise,
            ExplanatorySet += Candidate, break
//Sort Explanatoryset by Candidate.Surprise
Final = ExplanatorySet.SortDescend(Surprise)
Return Final.Take(3) // Top 3 most surprising

ATTRIBUTION FOR DERIVED MEASURES

- Why derived measures?

Below 20% threshold

Adver-tisr	Estimated Revenue	Actual Revenue	% change
Overall	100	90	-10
A1	50	**10**	400
A2	**0**	0	0
A3	**40**	70	-300
A4	**10**	10	0

Below 20% threshold

Adver-tisr	Estimated Clicks	Actual Clicks	% change
Overall	500	580	16
A1	100	**20**	-100
A2	**200**	360	200
A3	**100**	100	0
A4	**100**	100	0

Above 20% threshold

Adver-tisr	Estimated CPC	Actual CPC	% change
Overall	0.2	0.155	-22.5
A1	0.5	0.5	
A2	0	0	
A3	0.4	0.7	
A4	0.1	0.1	

- How do we attribute for derived measures?

Intuition: use expected value for all other elements and actual values for only this element

- **Captured by Partial Derivatives in Finite Difference Calculus**

F(.)/G(.) = (Delta_F*G – Delta_G*F)/(G * (G + Delta_G))

DEMO

Adtributor

EVALUATION

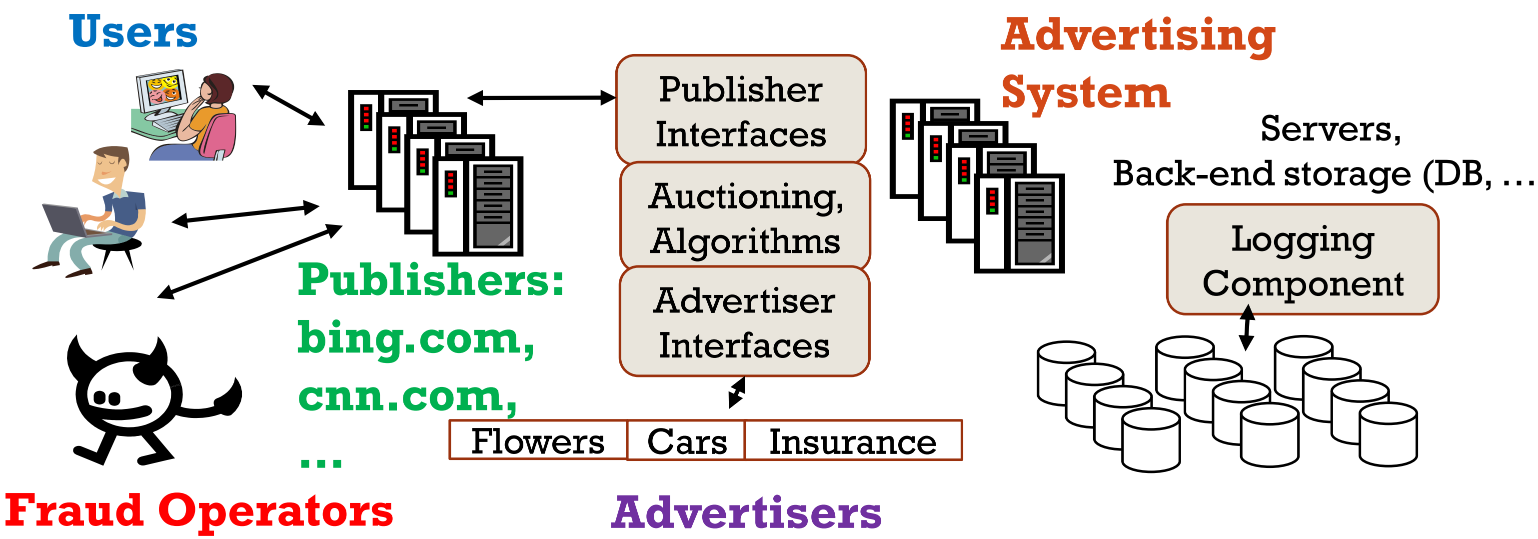
Parameter	Value
Anomalies	128
No. of matches	118
Manual errors	4
Adtributor's errors	5
Ambiguous	1
Accuracy	95.3%

- Evaluated 128 alerts generated over a 2 week period over 8 markets (US, UK, DE, FR: PC, Mobile for each)
- Compared Adtributor output with manual root-causing
- Time saved: 1+ hour on average per alert

RELATED WORK

	Root causing	Multiple Dimensions	Derived Measures
Network Component Failure Isolation (e.g., SCORE, Sherlock, etc.)	Explanatory Power, Succinctness	**Does not handle**	**Does not handle**
Network Traffic Pattern Finding (Autofocus, HHH)	Explanatory Power, Succinctness	Explores all combinations of dimensions *dynamically,* Heuristic: unexpectedness	**Does not handle**
Data mining (Summarization, Surprising Patterns)	Explanatory Power, Succinctness	Many techniques (e.g., Minimize description length)	**Does not handle**
Revenue Debugging	Explanatory Power, Succinctness	Explores single dimensions Pre-declared *statically* Surprise: JS divergence	Partial derivative, Finite differences

SUMMARY



- Algorithm for Root Cause Analysis in Advertising Systems
  - Uses explanatory power, succinctness, and surprise
- Attribution for derived measures
  - Finite difference, partial derivative-based approach
- Adtributor tool
  - 95+% accuracy, saves 1+ hour of manual troubleshooting time

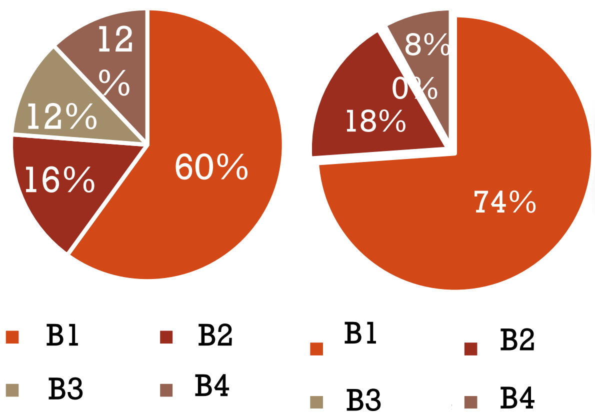
APPLYING OUR APPROACH MORE GENERALLY

- This problem/solution is not specific to advertising
- Datacenter Diagnostics problem (Bodik et al., Eurosys 2010)
  - Problem: When there is a slowdown in the datacenter, where is the slowdown? Is it CPU, Memory or Disk that is the bottleneck?
- Derived metric attribution
  - MoS score attribution in VOIP networks: which link is responsible for drop in the Mean Opinion Score (MoS) for a given VOIP call?

CASE STUDY: ANOMALOUS REVENUE DROP

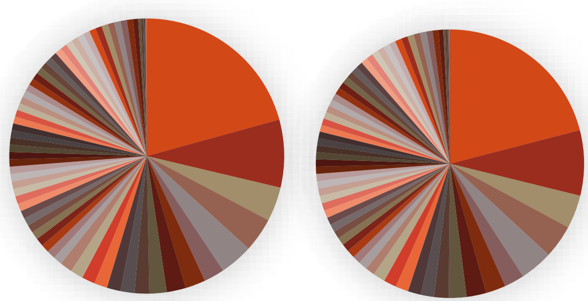
Dimension: Browser

Expected Actual



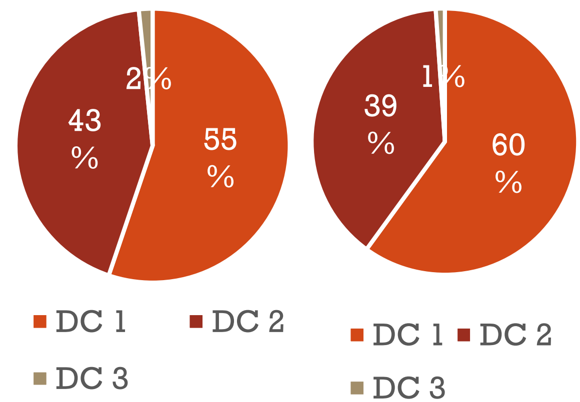
Dimension: Bucket

Expected Actual



Dimension: Data Center

Expected Actual



- ➢ Maximum surprise (deviation from expected value) seen for the browser dimension
  - Configuration error caused no ads to be shown on B3 for that time