

To Show or Not To Show: Using User Profiling to Manage Internet Advertisement Campaigns at Chitika

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How is an Internet Ad Served?

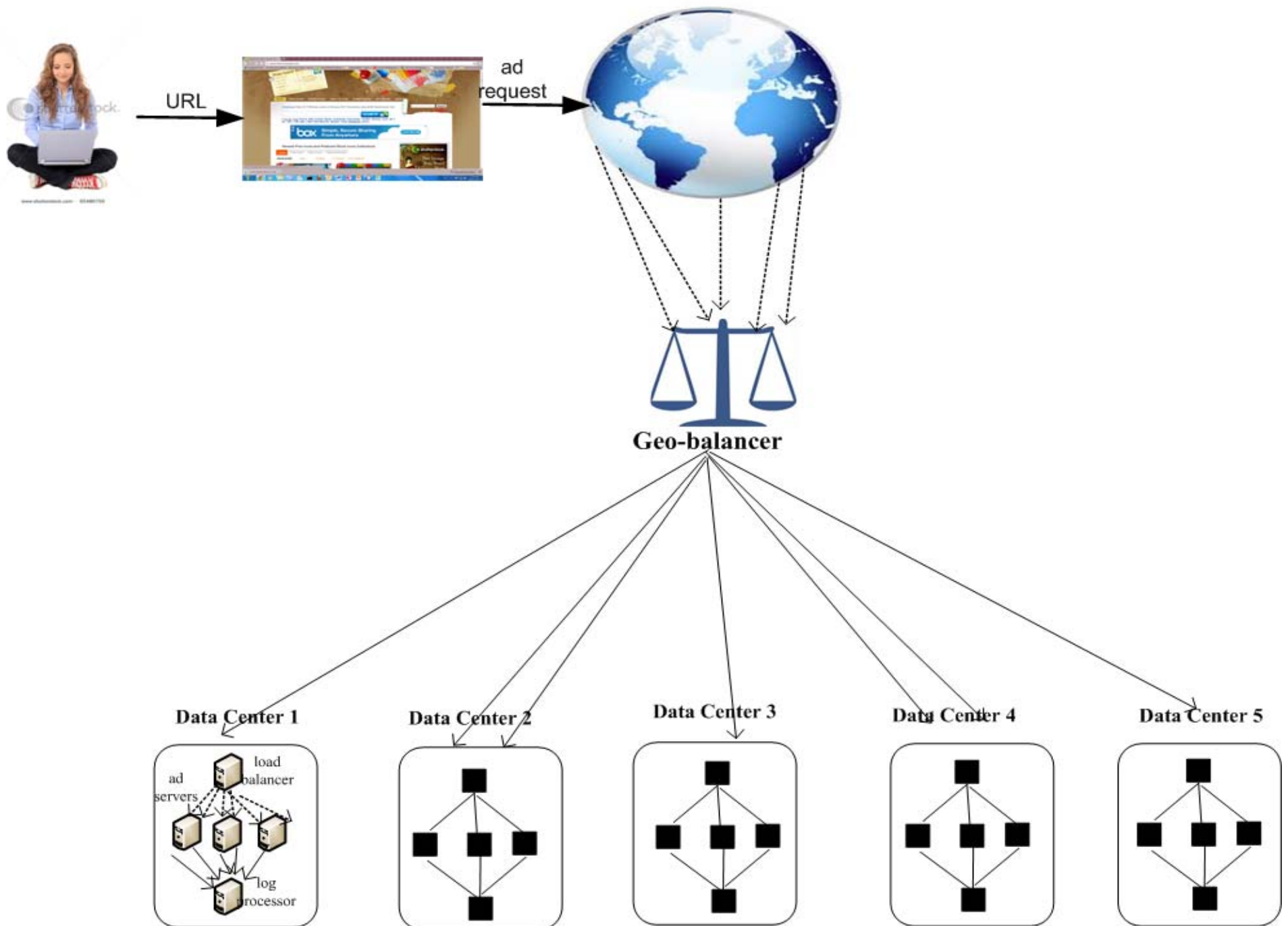


How is an Internet Ad Served?

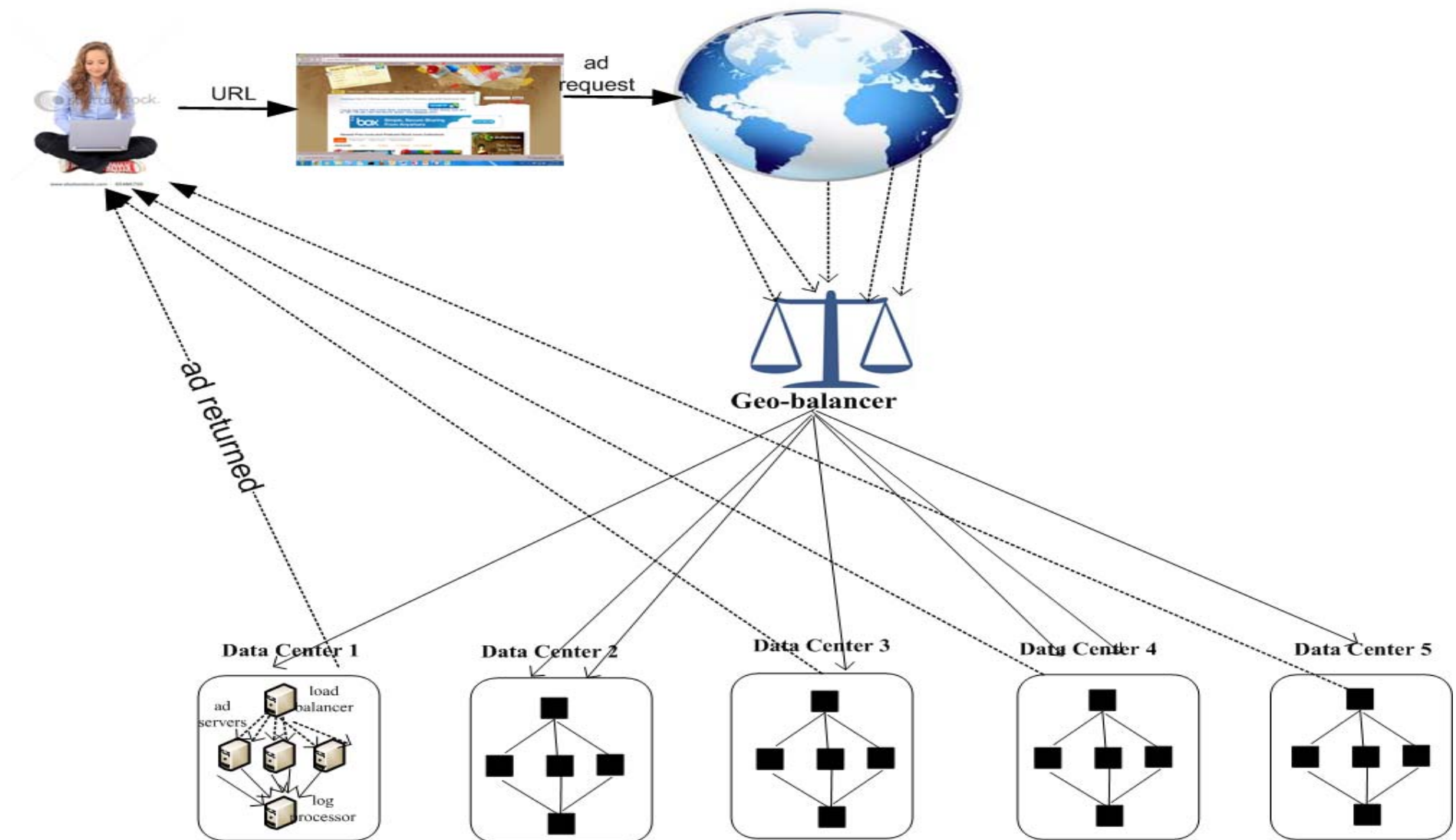


How is an Internet Ad Served?

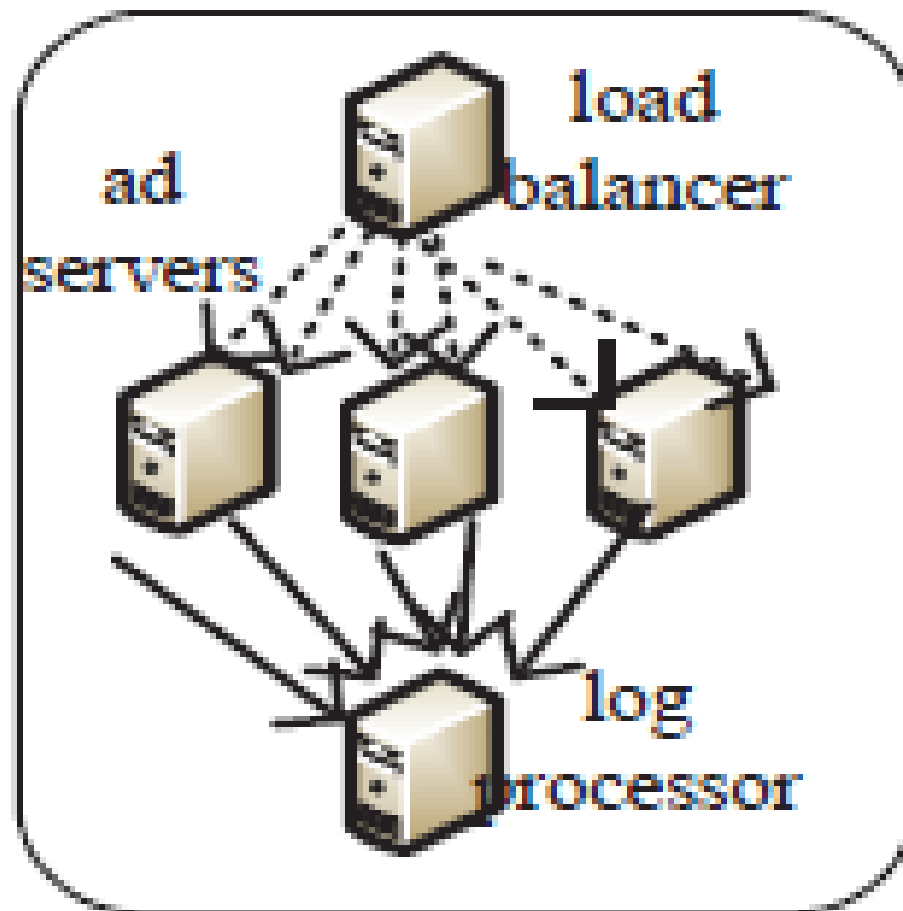




How is an Internet Ad Served?



Data Center 1



Internet Advertising Background

- Different players:
 - Advertiser, Ad Firm, Publisher, Web-user
- Perspective of the Ad-firm (Chitika)
- Usually, Pay per click Model
- Advertiser and Ad-firm only care about clicks
- However, publisher also cares about impressions.

To Show or Not to Show

- To respect the interests of the publisher, ads are only shown to users that are likely to click on them
- However, too much filtering can lead to a large loss of ad-revenue (clicks)
- **The goal therefore, is to maximize ad-revenue subject to an efficiency constraint**

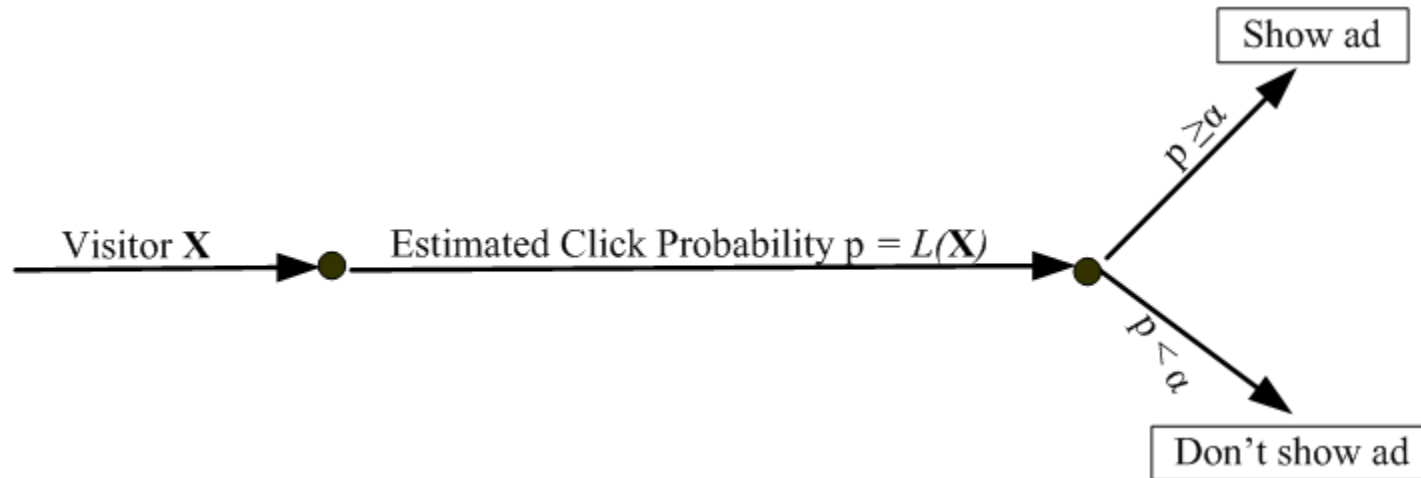
Solution: Show Ads to Select Users



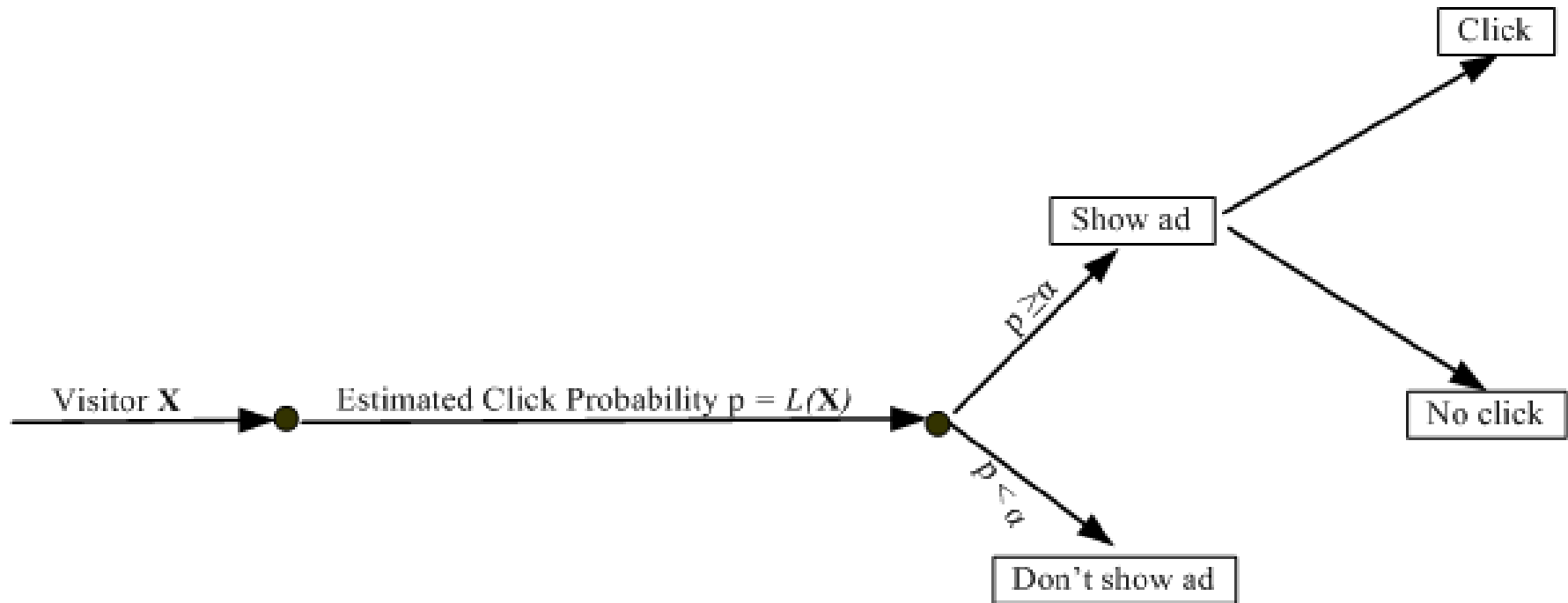
Solution: Show Ads to Select Users



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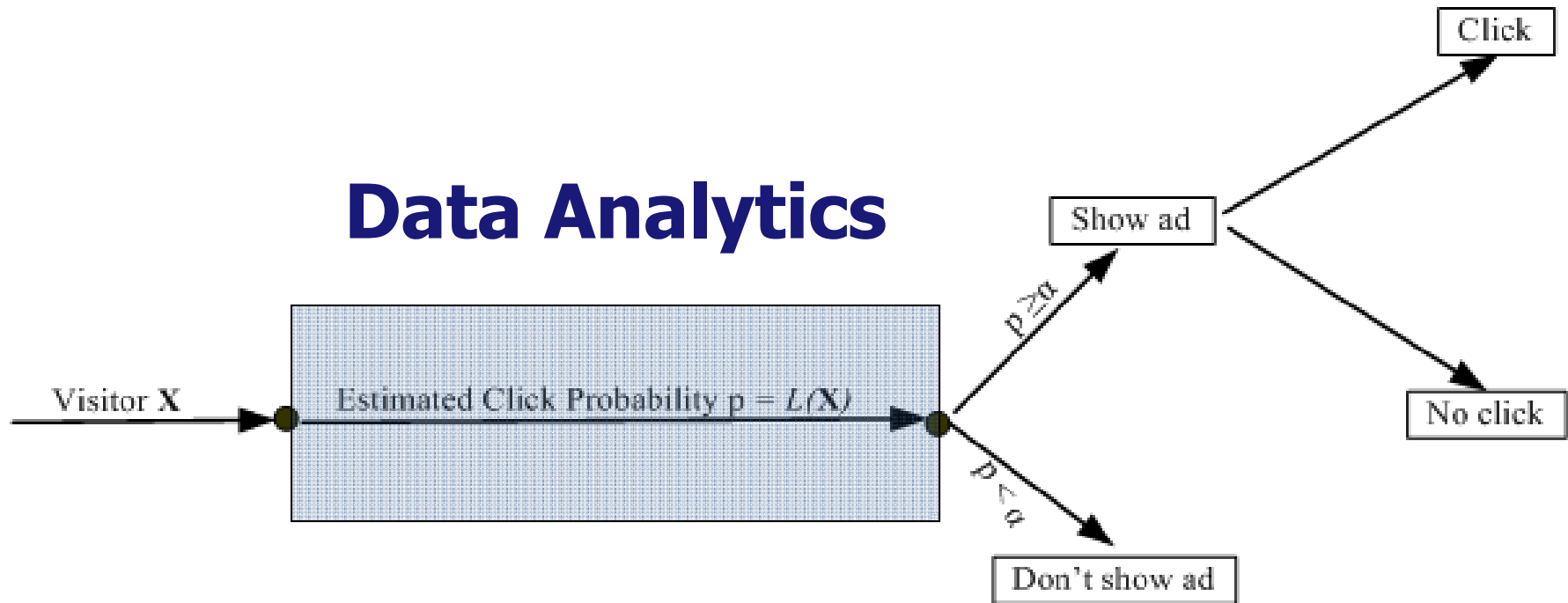


Solution: Show Ads to Select Users



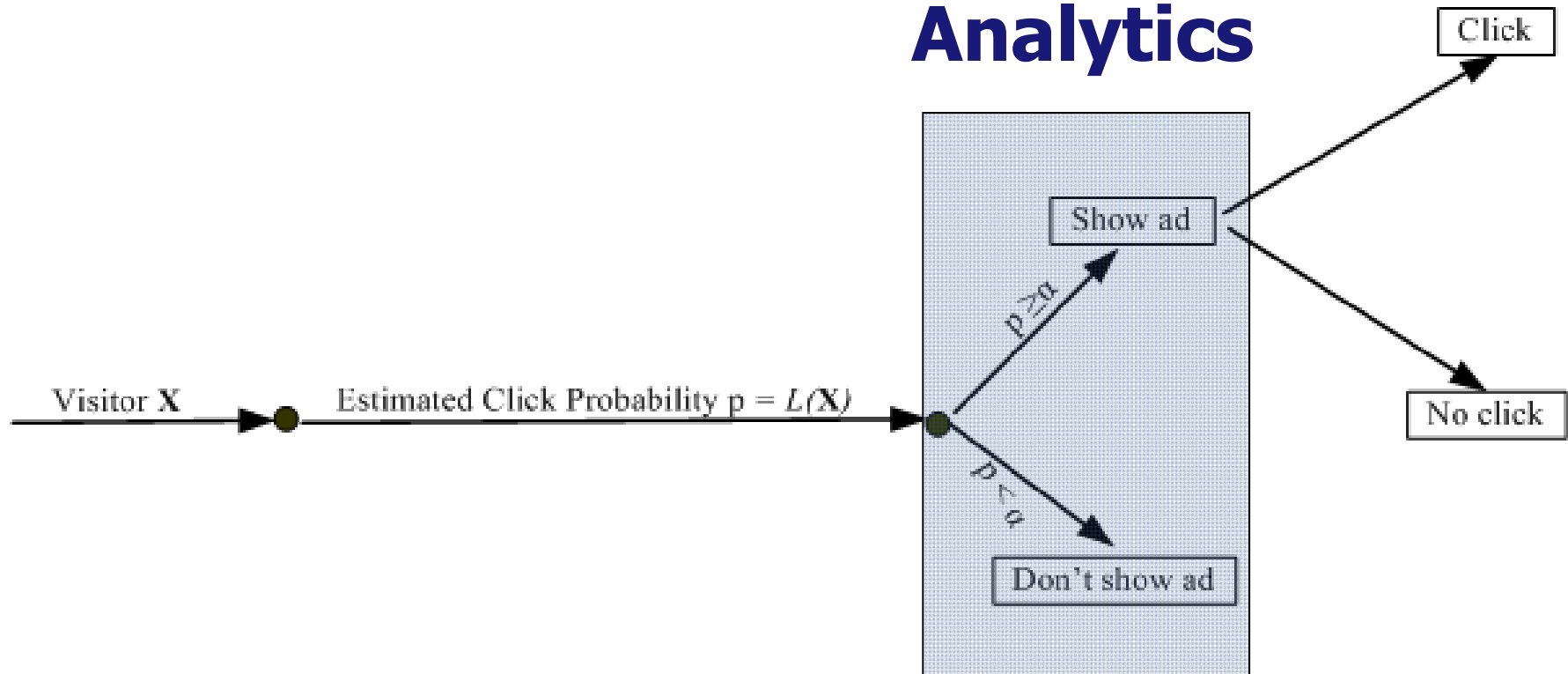
Solution: Show Ads to Select Users

Data Analytics



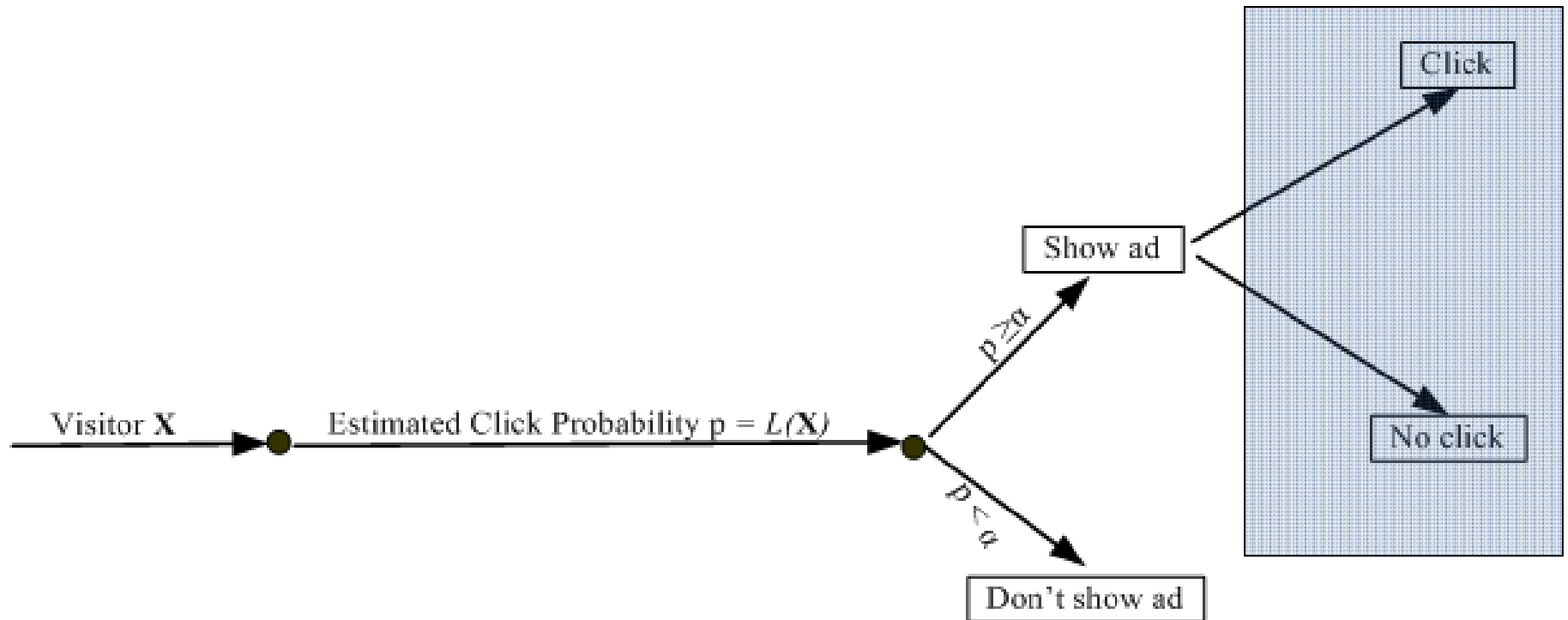
Solution: Show Ads to Select Users

Decision Analytics



Solution: Show Ads to Select Users

Real-time Feedback



Data Analytics

- Developed a predictive model called “Prophet”
 - Patent filed
- More than 50 predictor variables
- Uses Logit Model

$$\text{Click Probability} = f(\text{Predictor Variables})$$

Variable	Description	Possible Values
operating_system	Which operating system is being used by the visitor?	Linux, Android, Mac OS, Microsoft Windows, etc.
browser	Which browser is being used by the visitor?	Internet Explorer, Firefox, Chrome, Safari, Opera, etc.
search_engine	Which search engine is used by the visitor?	Google, Yahoo, Bing, etc.
btnSearch	Did the user click on the search engine button?	Yes, No
bad_speller	Is the visitor a bad speller?	Yes, No
search-string_type	Does the search string have local intent?	Yes, No
day	Day of the visit	Monday, Tuesday, . . . , Sunday
time	Time of the visit	Morning, Afternoon, Evening, Night
token_interest	Total number of clicks by this visitor in the past for ads on similar search strings	Integer
domain_token_interest	Total number of clicks by all the visitors in the past for ads on similar search strings	Integer
user_clicks	Total number of clicks by this visitor in the past	Integer
user_imps	Total number of impressions for this visitor in the past	Integer
height	Height of the ad unit	Numeric
width	Width of the ad unit	Numeric
loc_x	x-location of the ad	Numeric
loc_y	y-location of the ad	Numeric
CLICK	Dependent Variable Did the visitor click on the ad shown?	Yes, No

Table 1 There are more than 50 variables used in the Logit model; some of the important ones are shown here.

Variable	Description	Possible Values
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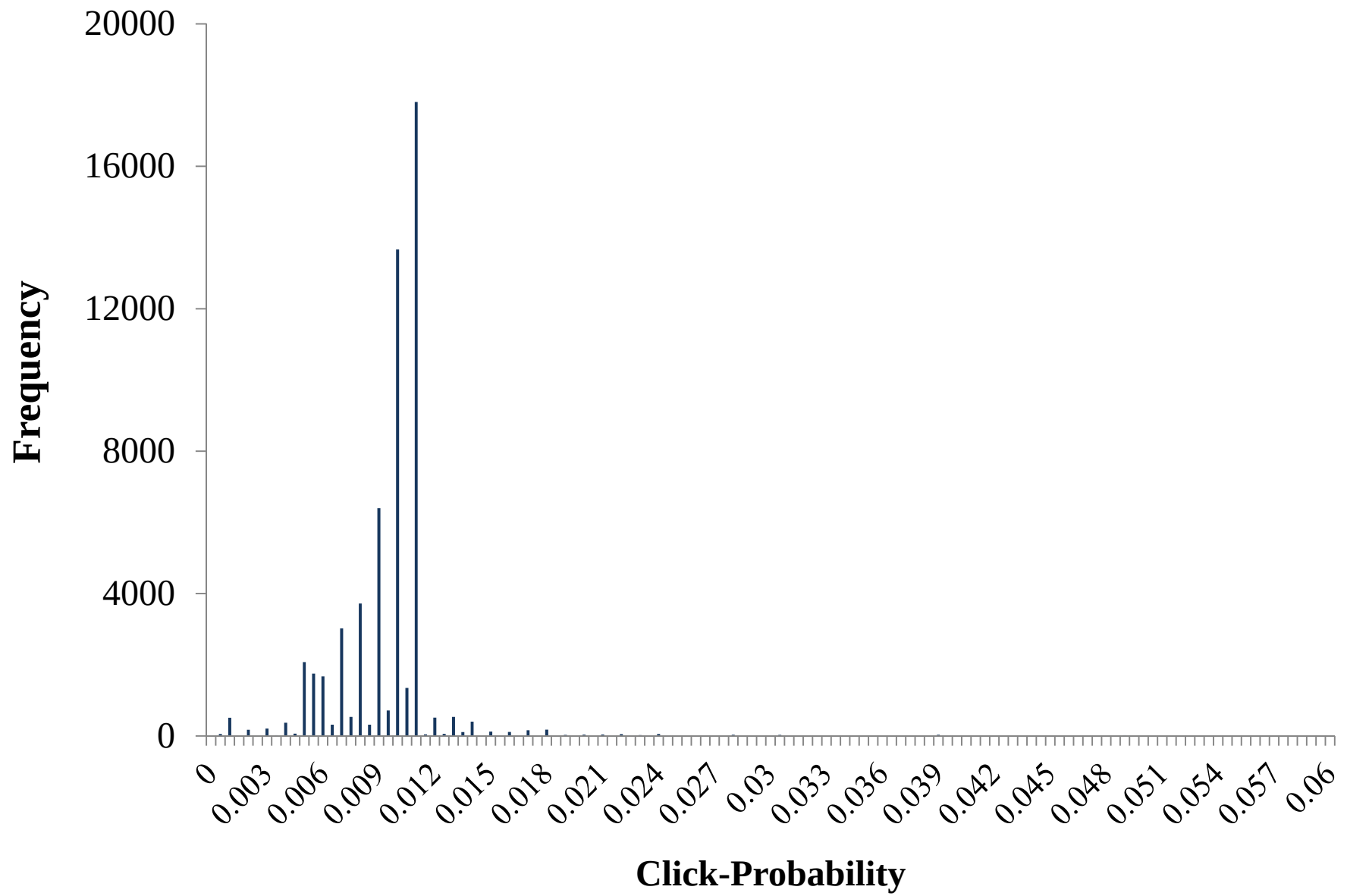
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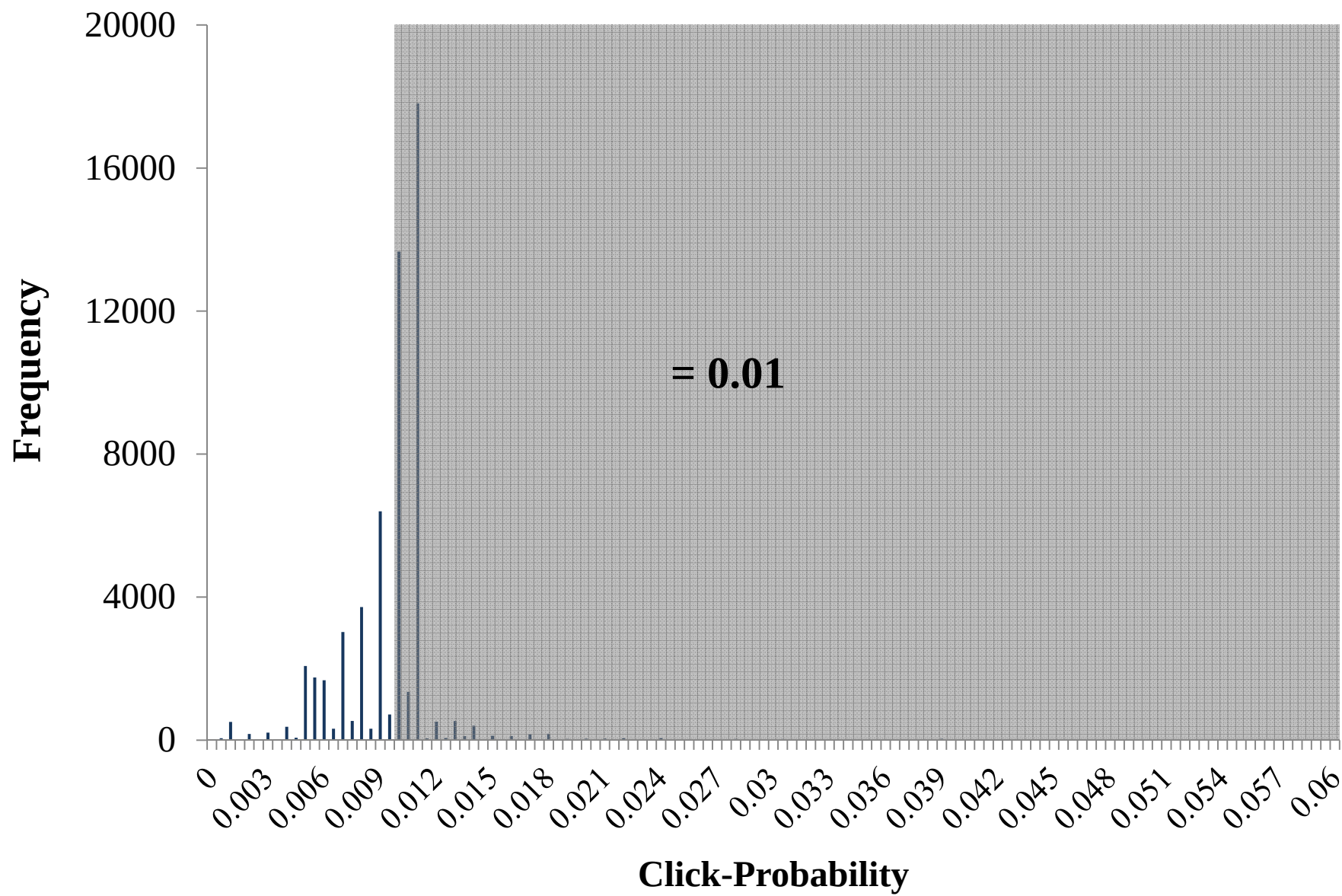
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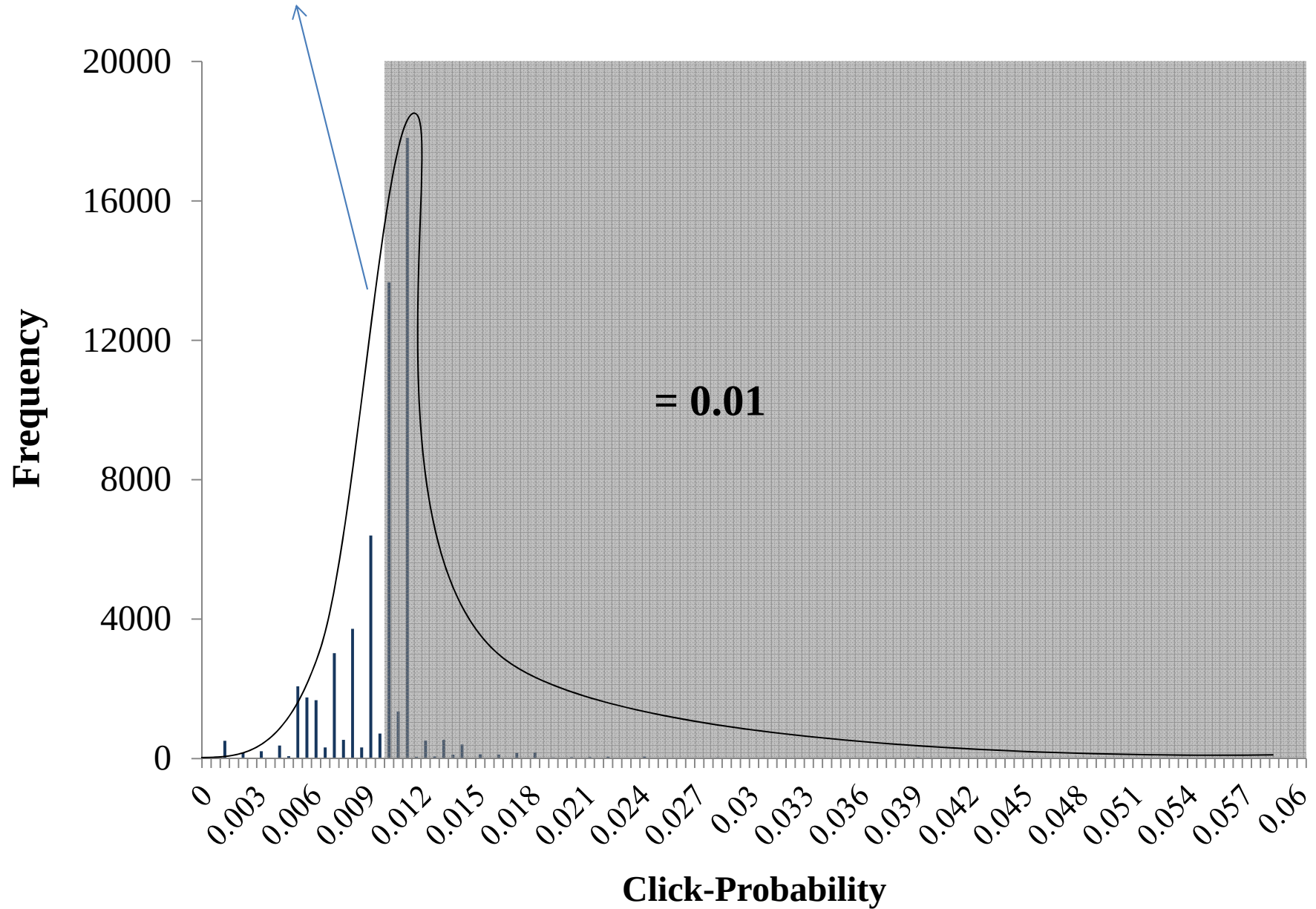
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Good match with the Beta Distribution



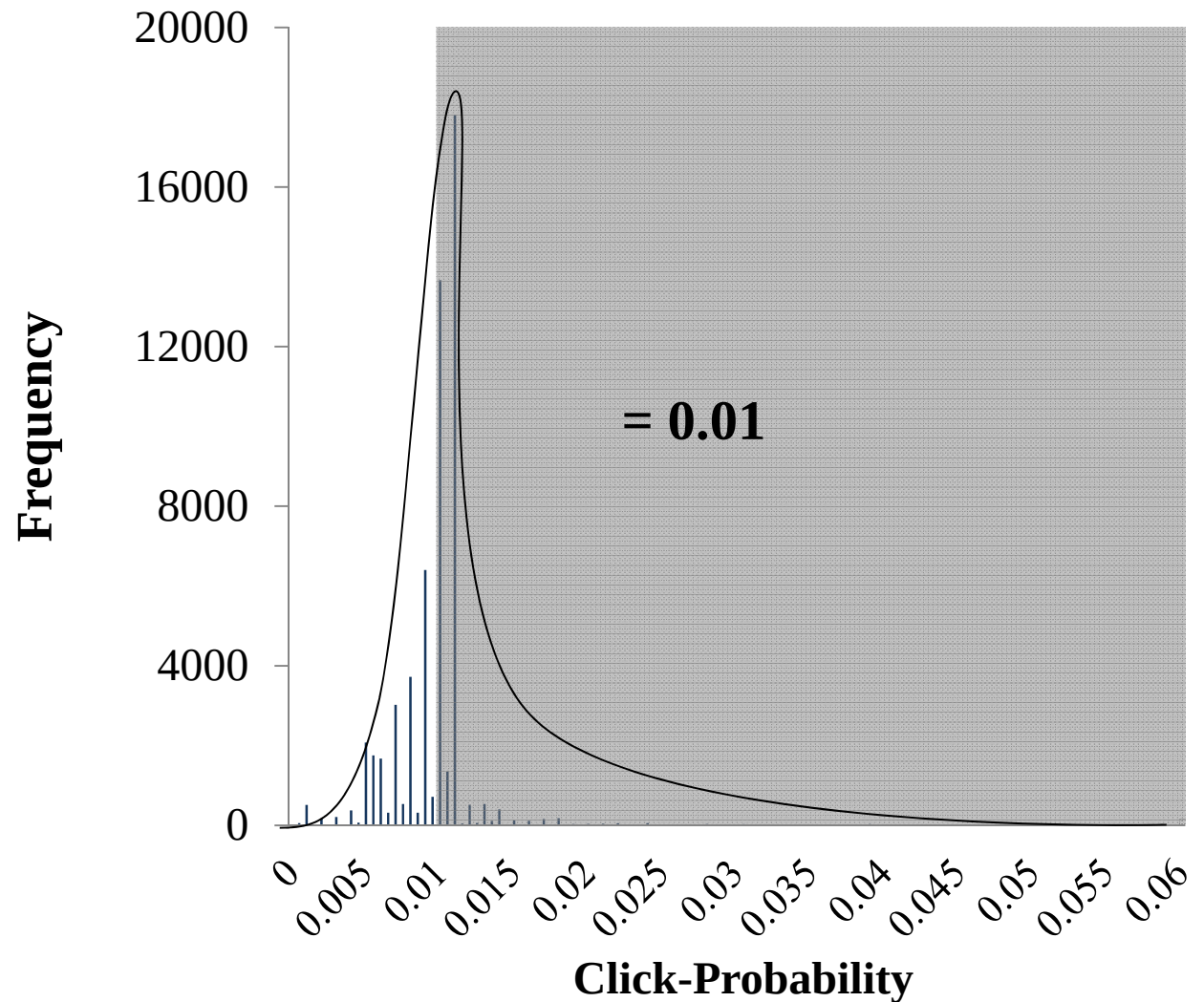
Impression probability

$$\gamma(\alpha) = \int_{\alpha}^1 f(p) dp$$

↓ ↓

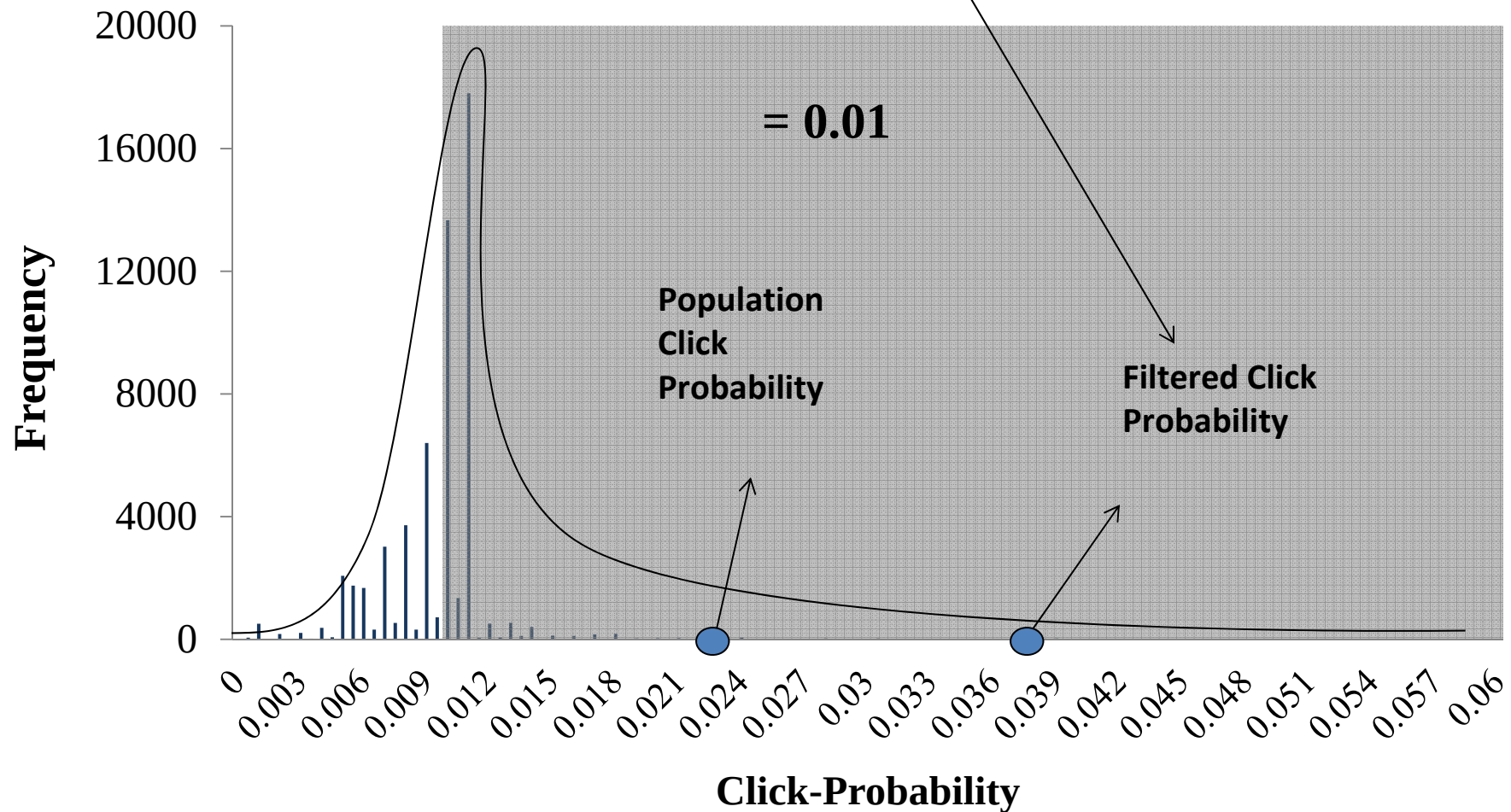
Probability Click
of probability
impression distribution

**This is clearly
decreasing in
alpha**



Filtered Click Probability

$$\delta(\alpha) = \frac{\int_{\alpha}^1 p f(p) dp}{\gamma(\alpha)}$$



Filtered Click probability

$$\delta(\alpha) = \frac{\int_{\alpha}^1 pf(p)dp}{\gamma(\alpha)}$$

$$\frac{d\delta(\alpha)}{d\alpha} = \frac{-\left(\int_{\alpha}^1 f(p)dp\right)\alpha f(\alpha) + f(\alpha)\left(\int_{\alpha}^1 pf(p)dp\right)}{(\gamma(\alpha))^2}$$

$$\int_{\alpha}^1 \alpha f(p)dp < \int_{\alpha}^1 pf(p)dp$$

$\delta(\alpha)$ is increasing in α

Maximize Clicks subject to a click-through-rate constraint

$$\max_{\alpha} E[\text{Number of Clicks in the Planning Horizon } (\tilde{r})]$$

Subject to

$$E\left[\frac{\text{Total Number of Clicks } (r_0 + \tilde{r})}{\text{Total Number of Impressions } (m_0 + \tilde{m})}\right] \geq$$

Publisher's Click-Through-Rate Constraint ()

Evaluating the Objective Function

$$E[\tilde{r}] = \sum_{i=0}^{K\lambda} \sum_{j=0}^i j \Pr[\tilde{r} = j | \tilde{m} = i] \Pr[\tilde{m} = i]$$

Expected number of clicks **Probability of generating j clicks from i impressions** **Probability of showing i impressions**

$$\Pr[\tilde{m} = i] = \binom{K\lambda}{i} (\gamma(\alpha))^i (1 - \gamma(\alpha))^{K\lambda-i}$$

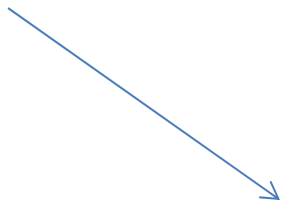
Probability of Impression

$$\Pr[\tilde{r} = j | \tilde{m} = i] = \binom{i}{j} (\delta(\alpha))^j (1 - \delta(\alpha))^{i-j}$$

Click probability given an impression

Evaluating the Objective Function

$$E[\tilde{r}] = \delta(\alpha) \sum_{i=0}^{K\lambda} i \binom{K\lambda}{i} (\gamma(\alpha))^i (1 - \gamma(\alpha))^{K\lambda-i} = K\lambda\delta(\alpha)\gamma(\alpha)$$

$$= K \int_{\alpha}^1 p f(p) dp$$


Thus objective is decreasing in α

Choose smallest α that meets
the click-through-rate constraint

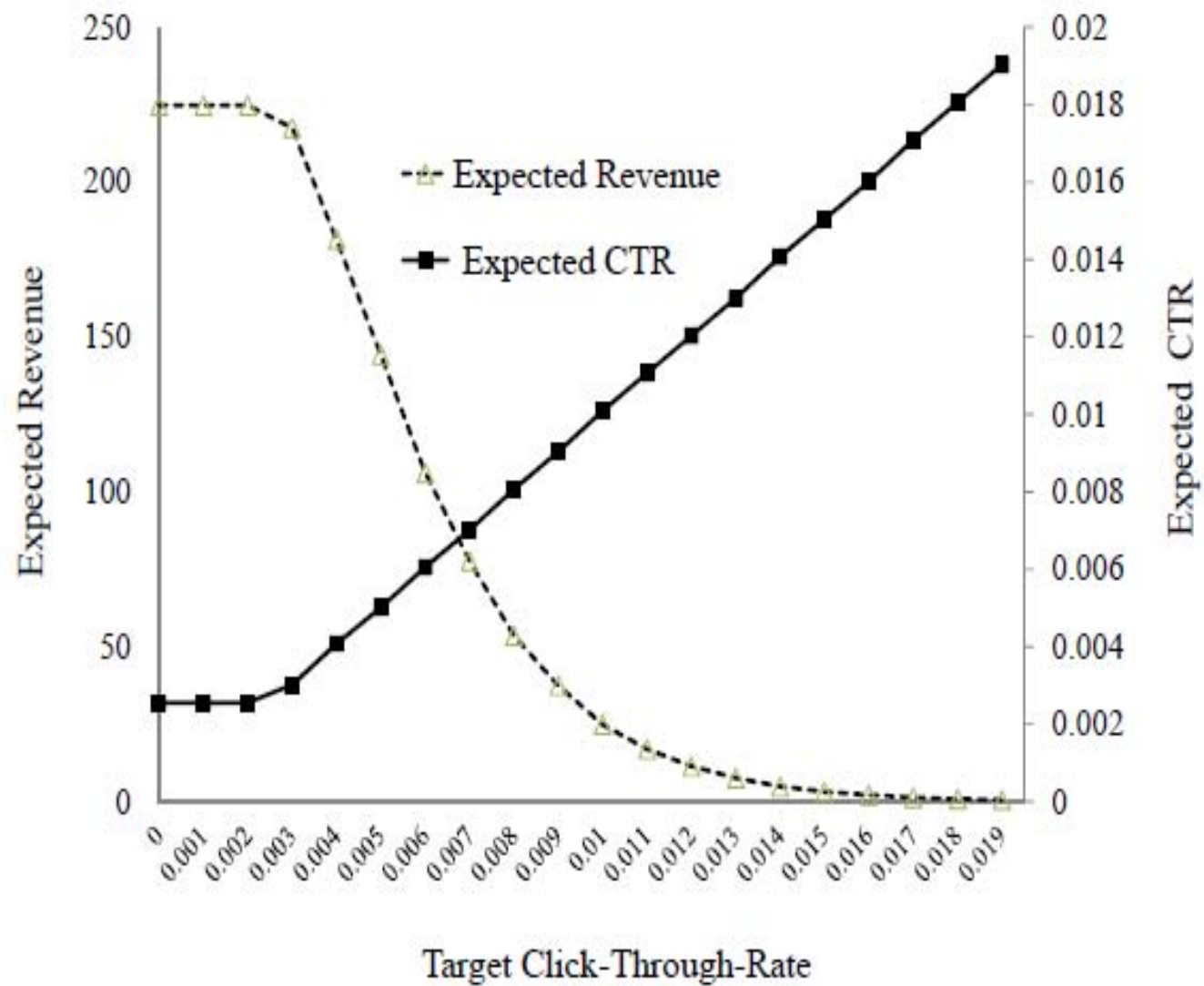


Figure 5 The slider provides a prediction of the revenue and the click-through-rate for any given ctr constraint.

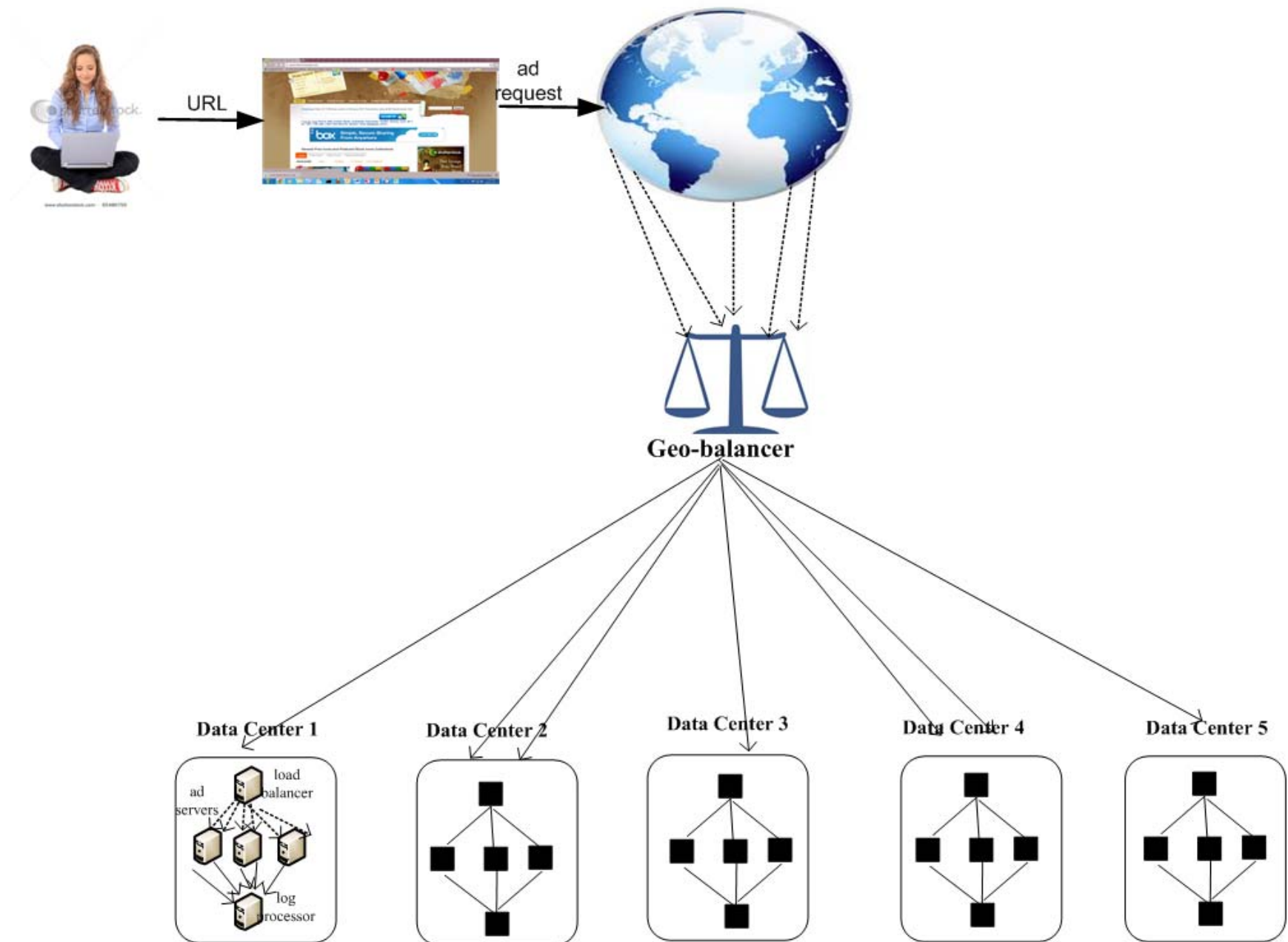
Static Versus Dynamic

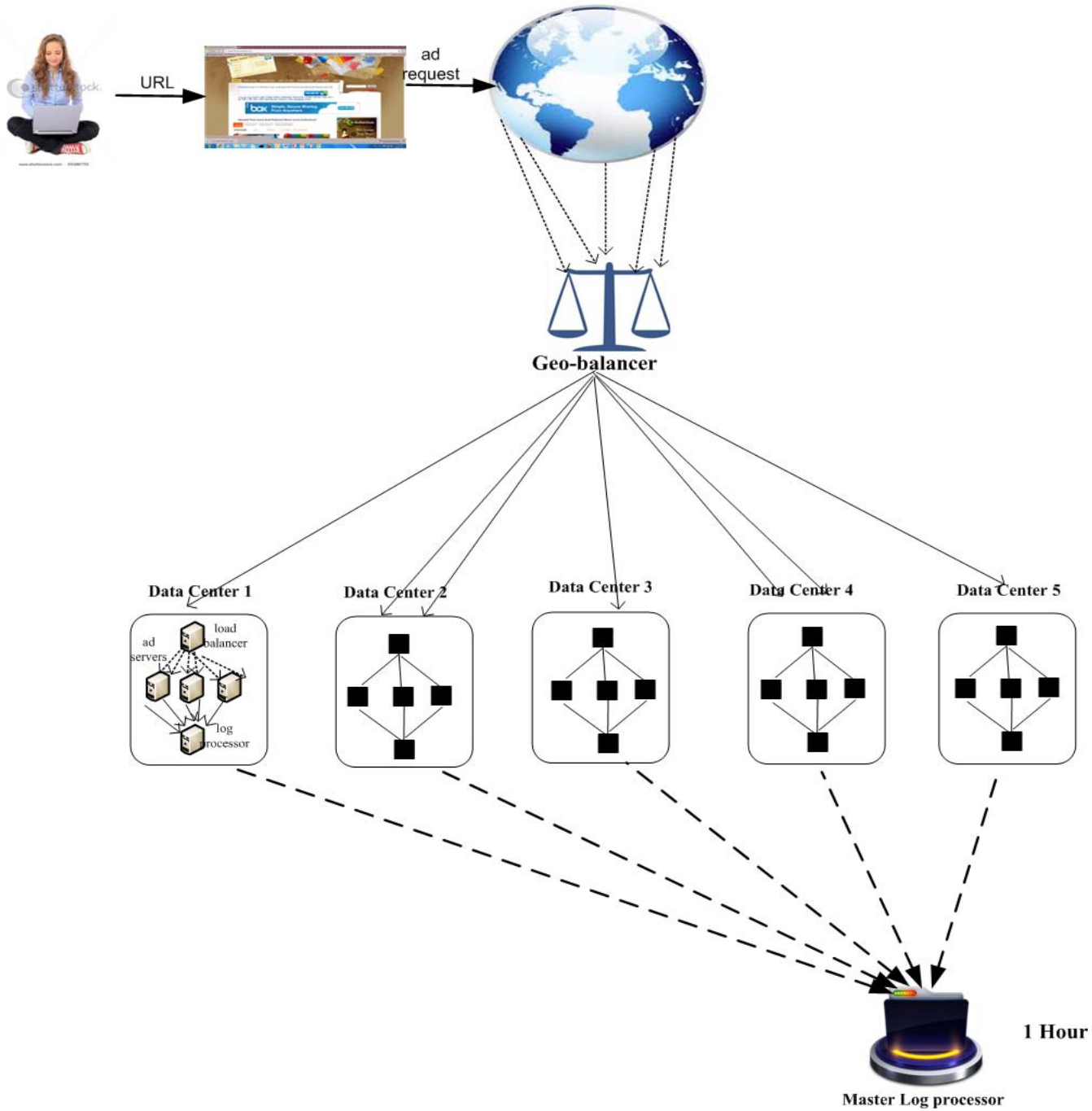
Day	0	1	2		K
Static	0				
Dynamic	0				
					Actual Number of Impressions
Static	0				
Dynamic	0				
					Actual Number of Clicks
Static	0.0082				
Dynamic	0.0082				
					Decision Variable (α)

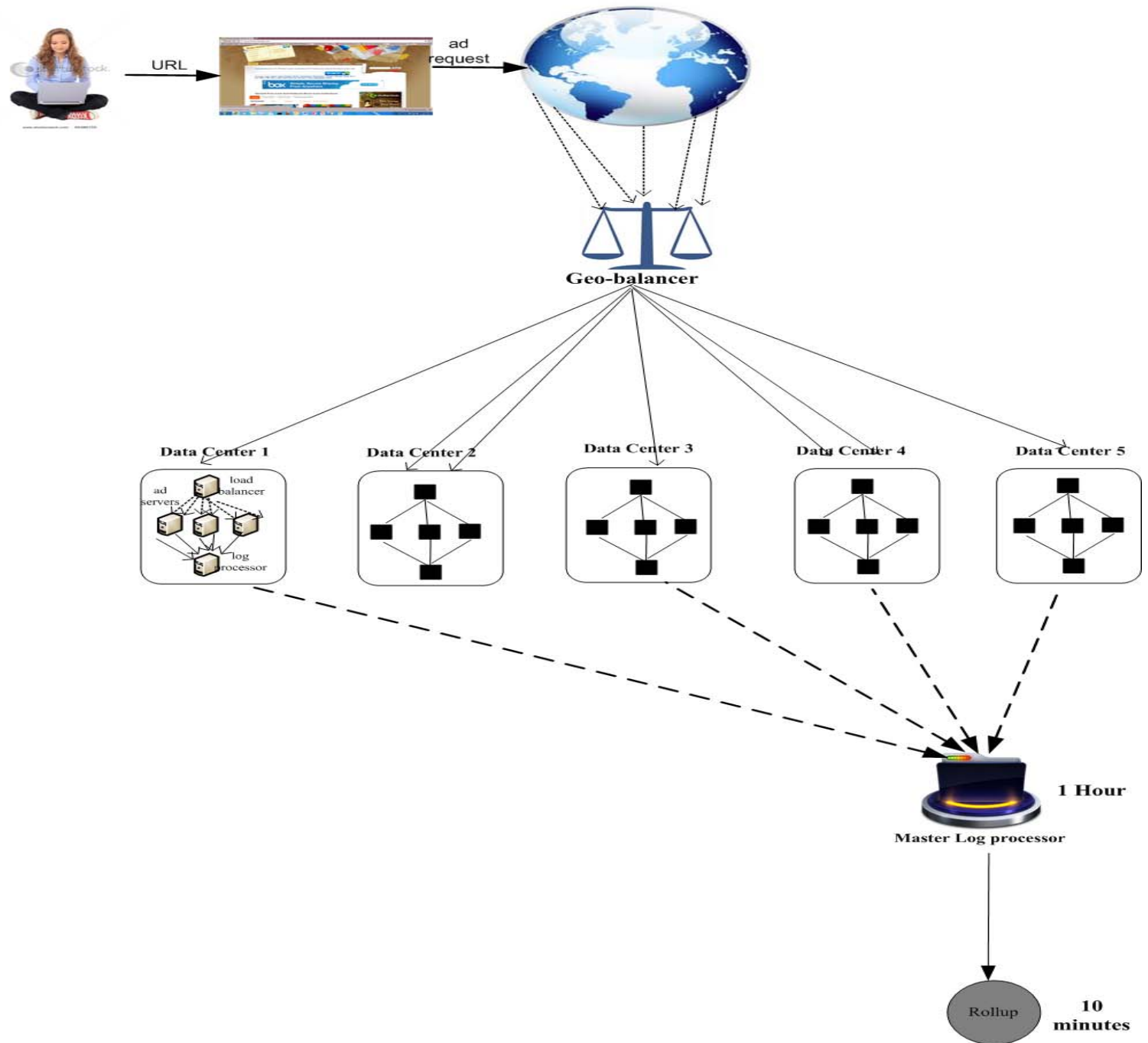
Evaluating the Constraint

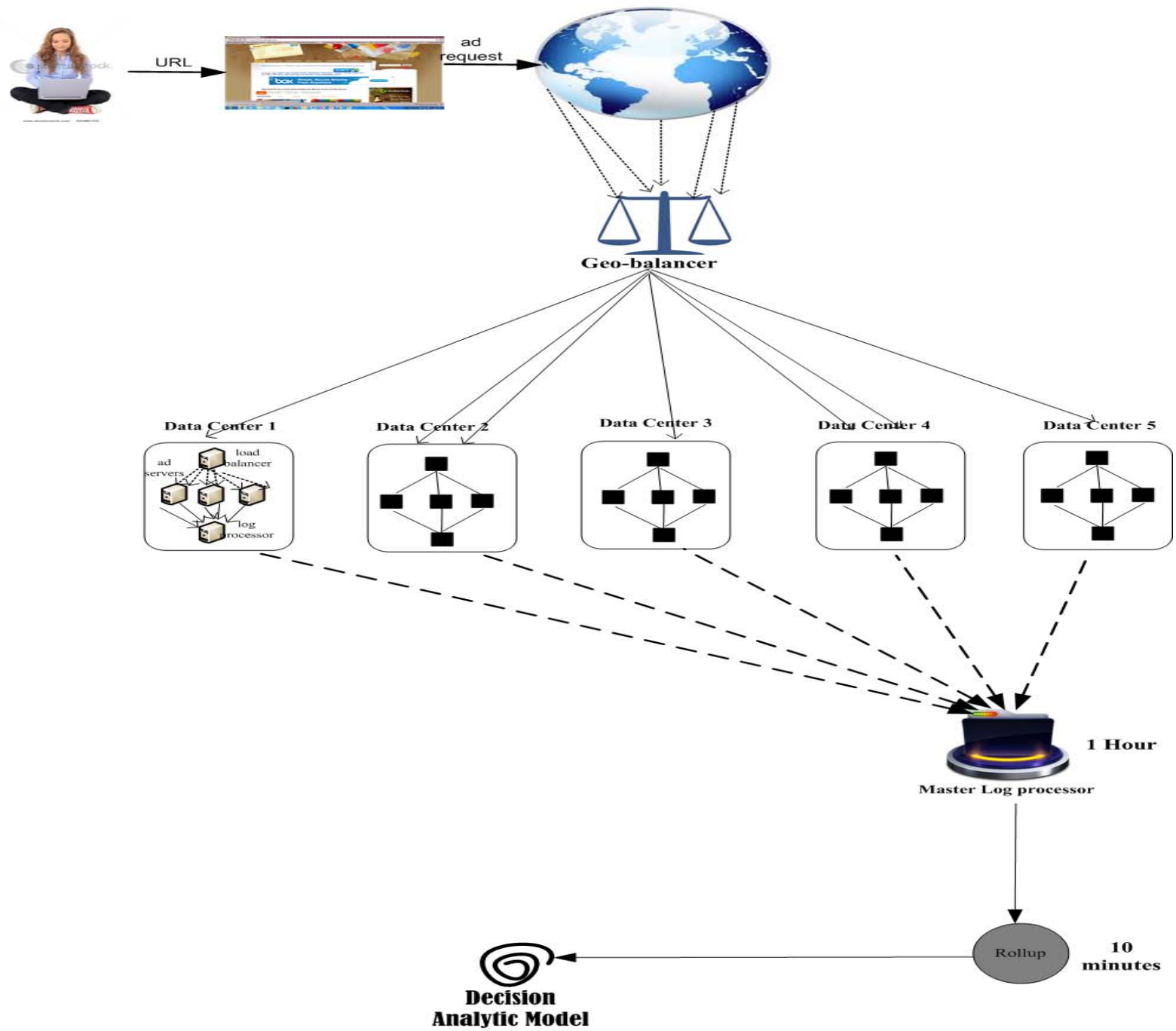
$$\mathbb{E} \left[\frac{r_0 + \tilde{r}}{m_0 + \tilde{m}} \right] \geq \eta$$

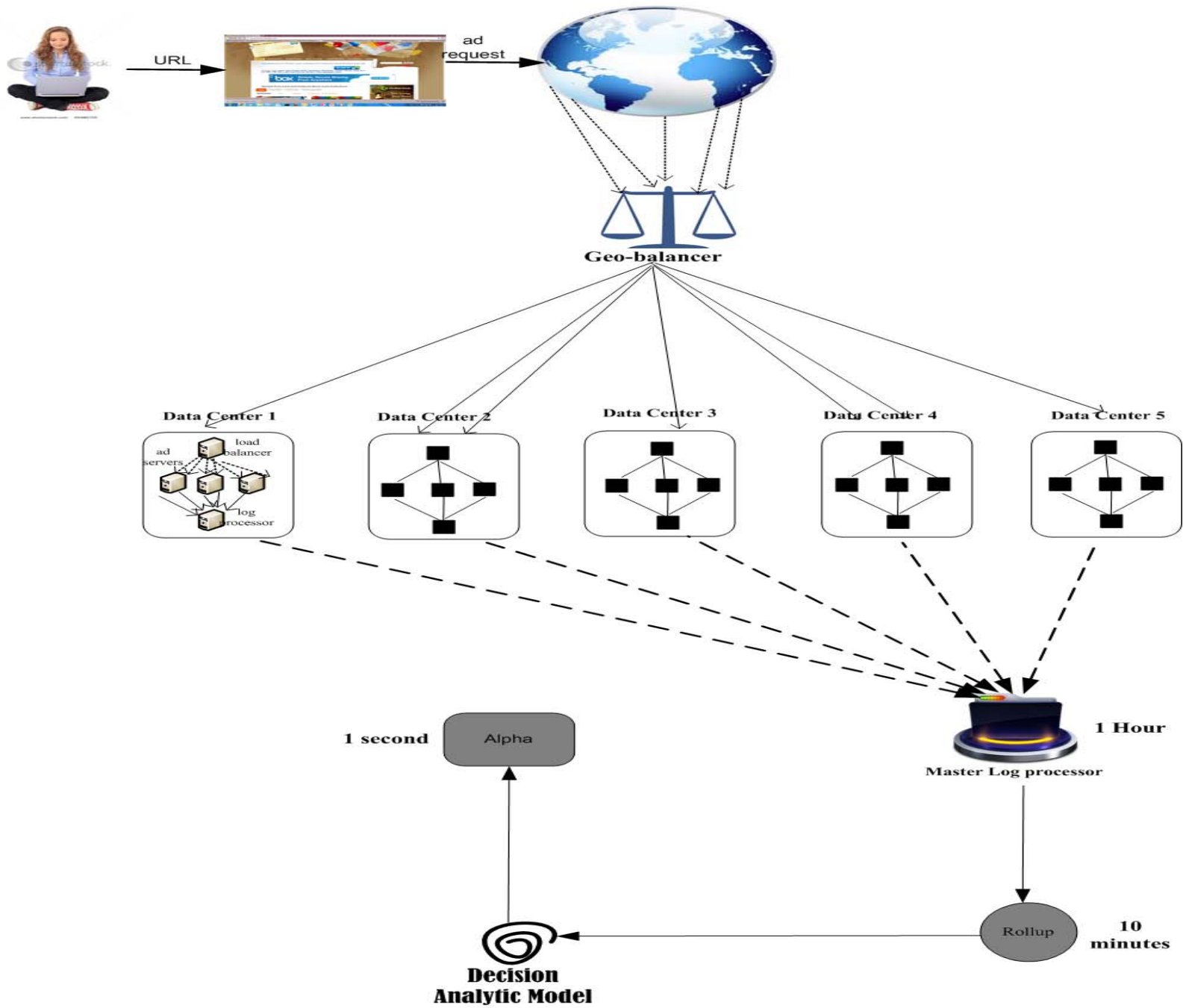
- Need to do a double summation where the number of evaluations can be in the order of the square of the number of arrivals in the rest of the horizon
- This number can be quite large
 - typically 30 times 100,000
- Also, the constraint needs to be calculated for each value of
 - the lowest alpha that meets the threshold is what we need
- For the dynamic case, we need recalculate in each period

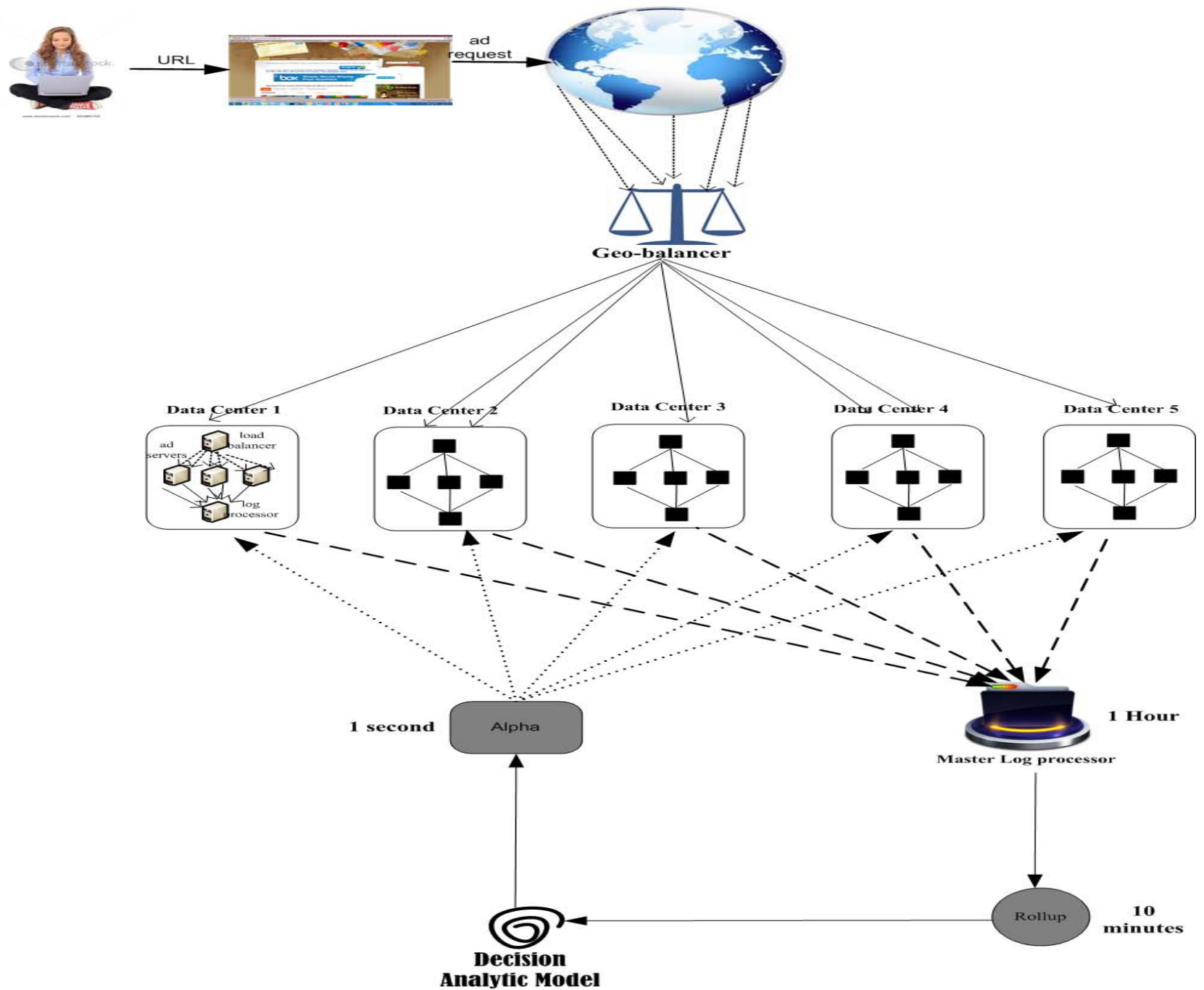


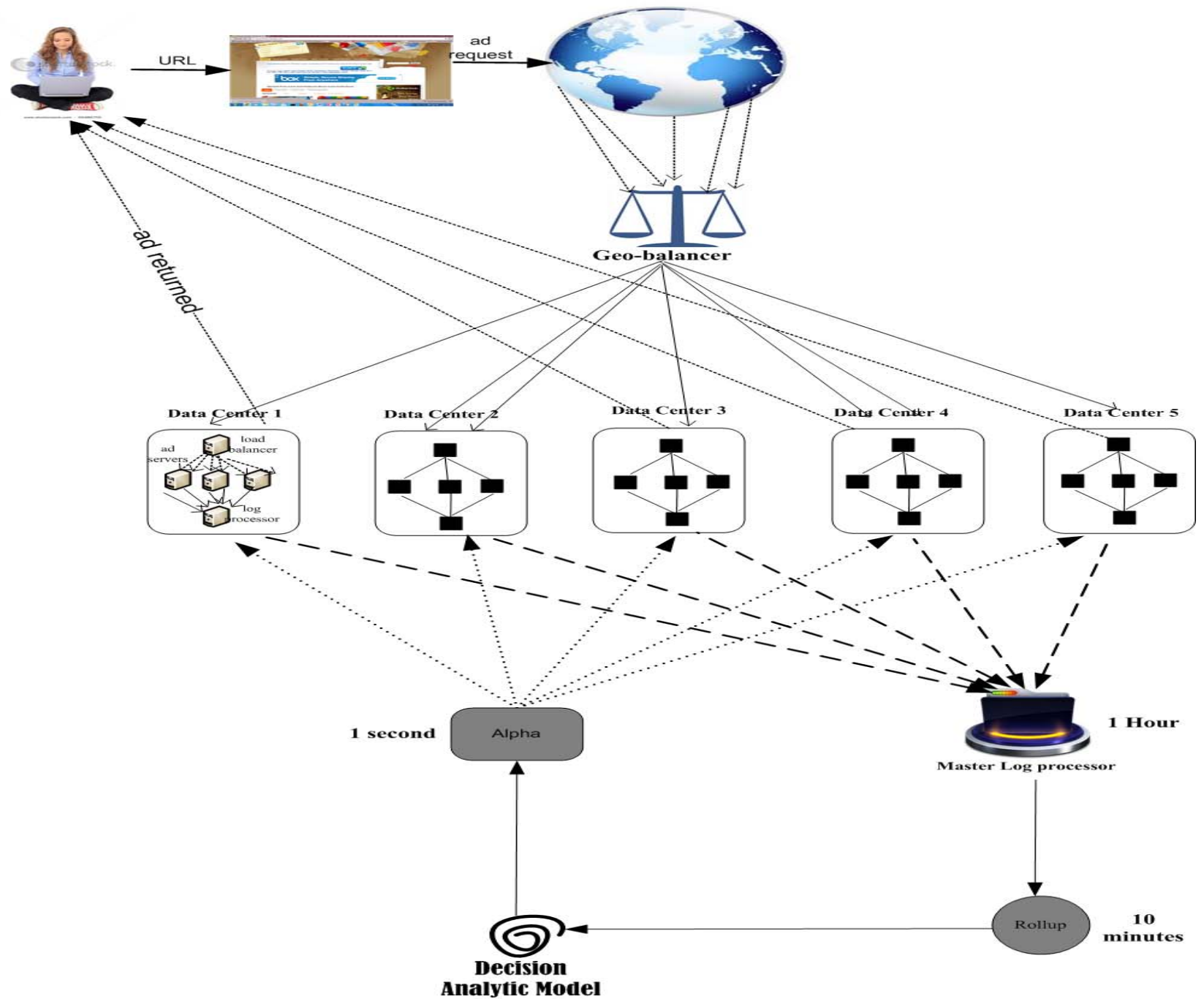












Evaluating the Constraint

- The dynamic approach is attractive
- However, it takes long to update even with fast computers.
 - >150,000 publishers
- So, an approximate method is indicated

Approximation

$$E \left[\frac{r_0 + \tilde{r}}{m_0 + \tilde{m}} \right]$$

←
Expectation of Ratio
(Exact)

Approximation

$$E \left[\frac{r_0 + \tilde{r}}{m_0 + \tilde{m}} \right] \approx \frac{r_0 + k\lambda\delta(\alpha)\gamma(\alpha)}{m_0 + k\lambda\gamma(\alpha)}$$

←
Expectation of Ratio
(Exact)

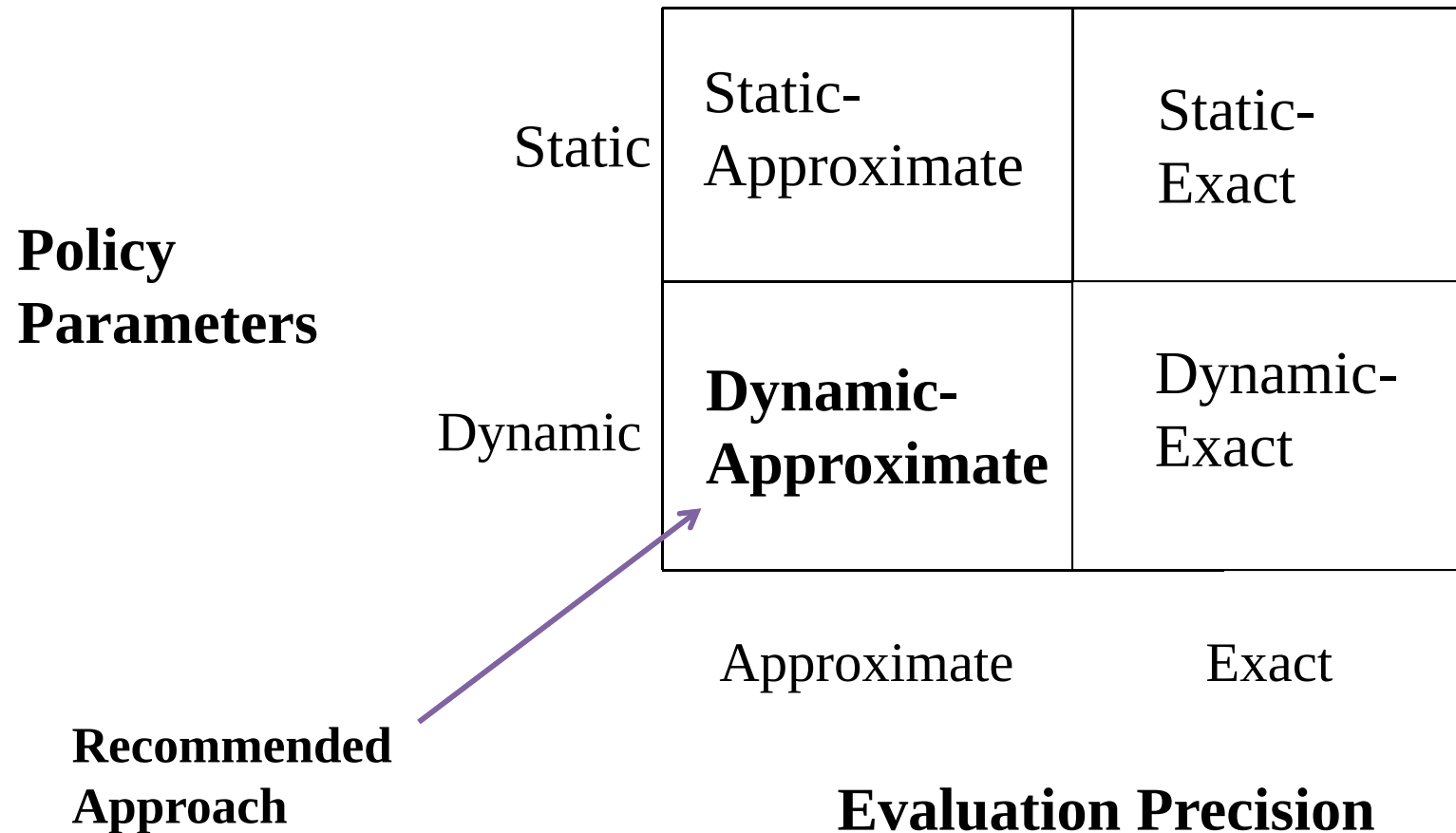
→
Ratio of Expectations
(Approximate)

- Second order Taylor's series with 2 variables

$$\begin{aligned} E \left(\frac{x}{y} \right) &= \frac{E(x)}{E(y)} + \frac{1}{2} \left[\frac{2COV(x, y)}{E(y)^2} + \frac{2V(y)}{E(y)^3} \right] \\ &= \frac{E(r_0 + r)}{E(m_0 + m)} + \frac{np_1p_2q_2}{(m_0 + np_2)^2} + \frac{np_2q_2}{(m_0 + np_2)^3} \end{aligned}$$

- All but the first term vanish for large numbers of arrivals

Solution Approaches



Exact vs. Approximate

		Dynamic-Exact				Dynamic-Approximate				Static-Exact			Static-Approximate		
<i>K</i>	<i>h</i>	<i>m</i>	<i>r</i>	CTR	CPU Secs	<i>m</i>	<i>r</i>	CTR	CPU Secs	<i>m</i>	<i>r</i>	CTR	<i>m</i>	<i>r</i>	CTR
3	0.005	17377	166	0.00955	294	17377	166	0.00955	0	16438	165	0.01004	16438	165	0.010038
3	0.0075	14207	158	0.01112	621	14207	158	0.01112	0.01	7142	132	0.01848	7142	132	0.018482
3	0.01	10973	137	0.01249	889	10973	137	0.01249	0.016	2392	79	0.03303	2392	79	0.033027
3	0.0125	5927	74	0.01249	1276	5927	74	0.01249	0.026	1493	53	0.0355	1493	53	0.035499
3	0.015	4681	65	0.01389	1455	4681	65	0.01389	0.032	867	41	0.04729	867	41	0.04729
3	0.02	3204	54	0.01685	4934	3204	54	0.01685	0.098	513	26	0.05068	513	26	0.050682
6	0.005	35135	325	0.00925	1730	35135	325	0.00925	0	32905	321	0.00976	32905	321	0.009755
6	0.0075	31174	316	0.01014	3113	31174	316	0.01014	0	14210	252	0.01773	14210	252	0.017734
6	0.01	26258	288	0.01097	4967	26258	288	0.01097	0	4783	149	0.03115	4783	149	0.031152
6	0.0125	20542	260	0.01266	6035	20542	260	0.01266	0.01	3009	107	0.03556	3009	107	0.03556
6	0.015	14181	226	0.01594	7817	14181	226	0.01594	0.015	1754	78	0.04447	1754	78	0.04447
6	0.02	8819	183	0.02075	14035	8819	183	0.02075	0.04	1039	47	0.04524	1039	47	0.045236
9	0.005	52854	486	0.0092	5156	52854	486	0.0092	0	49335	483	0.00979	49335	483	0.00979
9	0.0075	48299	477	0.00988	9574	48299	477	0.00988	0	21509	384	0.01785	21509	384	0.017853
9	0.01	40790	445	0.01091	14170	40790	445	0.01091	0.019	7256	227	0.03128	7256	227	0.031284
9	0.0125	28016	358	0.01278	18650	28016	358	0.01278	0.031	4607	170	0.0369	4607	170	0.0369
9	0.015	21097	326	0.01545	22166	21097	326	0.01545	0.047	2716	125	0.04602	2716	125	0.046024
9	0.02	12736	275	0.02159	29033	12736	275	0.02159	0.016	1595	74	0.04639	1595	74	0.046395

Exact vs. Approximate

		Dynamic-Exact				Dynamic-Approximate				Static-Exact			Static-Approximate		
<i>K</i>	<i>h</i>	<i>m</i>	<i>r</i>	CTR	CPU Secs	<i>m</i>	<i>r</i>	CTR	CPU Secs	<i>m</i>	<i>r</i>	CTR	<i>m</i>	<i>r</i>	CTR
3	0.005	17377	166	0.00955	294	17377	166	0.00955	0	16438	165	0.01004	16438	165	0.010038
3	0.0075	14207	158	0.01112	621	14207	158	0.01112	0.01	7142	132	0.01848	7142	132	0.018482
3	0.01	10973	137	0.01249	889	10973	137	0.01249	0.016	2392	79	0.03303	2392	79	0.033027
3	0.0125	5927	74	0.01249	1276	5927	74	0.01249	0.026	1493	53	0.0355	1493	53	0.035499
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3	0.02	3204	54	0.01685	4934	3204	54	0.01685	0.098	513	26	0.05068	513	26	0.050682
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6	0.0075	31174	316	0.01014	3113	31174	316	0.01014	0	14210	252	0.01773	14210	252	0.017734
6	0.01	26258	288	0.01097	4967	26258	288	0.01097	0	4783	149	0.03115	4783	149	0.031152
6	0.0125	20542	260	0.01266	6035	20542	260	0.01266	0.01	3009	107	0.03556	3009	107	0.03556
6	0.015	14181	226	0.01594	7817	14181	226	0.01594	0.015	1754	78	0.04447	1754	78	0.04447
6	0.02	8819	183	0.02075	14035	8819	183	0.02075	0.04	1039	47	0.04524	1039	47	0.045236
9	0.005	52854	486	0.0092	5156	52854	486	0.0092	0	49335	483	0.00979	49335	483	0.00979
9	0.0075	48299	477	0.00988	9574	48299	477	0.00988	0	21509	384	0.01785	21509	384	0.017853
9	0.01	40790	445	0.01091	14170	40790	445	0.01091	0.019	7256	227	0.03128	7256	227	0.031284
9	0.0125	28016	358	0.01278	18650	28016	358	0.01278	0.031	4607	170	0.0369	4607	170	0.0369
9	0.015	21097	326	0.01545	22166	21097	326	0.01545	0.047	2716	125	0.04602	2716	125	0.046024
9	0.02	12736	275	0.02159	29033	12736	275	0.02159	0.016	1595	74	0.04639	1595	74	0.046395

Dynamic vs. Static

	DYNAMIC				STATIC			
Day	Alpha	Impressions	Clicks	CTR	Alpha	Impressions	Clicks	CTR
1	0.0082	1036	38	0.03668	0.0082	1036	38	0.03668
2	0.006	3850	68	0.017662	0.0082	2226	58	0.026056
3	0.0059	5874	119	0.020259	0.0082	3090	91	0.02945
4	0.005	9845	167	0.016963	0.0082	4236	120	0.028329
5	0.0048	13996	220	0.015719	0.0082	5312	143	0.02692
6	0.0046	17655	269	0.015236	0.0082	6129	168	0.027411
7	0.0043	22551	320	0.01419	0.0082	7361	197	0.026763
8	0.0042	27164	355	0.013069	0.0082	8309	216	0.025996
9	0.0043	31468	424	0.013474	0.0082	9298	255	0.027425
10	0.0039	36681	496	0.013522	0.0082	10609	298	0.028089
11	0.0036	41710	543	0.013018	0.0082	11461	322	0.028095
12	0.0035	46865	606	0.012931	0.0082	12495	354	0.028331
13	0.0033	52338	661	0.012629	0.0082	13747	393	0.028588
14	0.0032	57598	703	0.012205	0.0082	14522	409	0.028164
15	0.0032	63006	765	0.012142	0.0082	15642	445	0.028449
16	0.003	68626	810	0.011803	0.0082	16762	465	0.027741
17	0.0031	73944	863	0.011671	0.0082	17581	498	0.028326
18	0.003	79527	918	0.011543	0.0082	18763	532	0.028354
19	0.0028	85139	953	0.011193	0.0082	19775	550	0.027813
20	0.003	90515	1021	0.01128	0.0082	20731	585	0.028219
21	0.0026	96285	1070	0.011113	0.0082	21938	608	0.027714
22	0.0026	101945	1132	0.011104	0.0082	22837	636	0.02785
23	0.0023	107689	1178	0.010939	0.0082	23798	657	0.027607
24	0.0023	113529	1228	0.010817	0.0082	25054	687	0.027421
25	0.0022	119316	1271	0.010652	0.0082	25891	709	0.027384
26	0.0022	125127	1351	0.010797	0.0082	26994	752	0.027858
27	0.0013	131053	1421	0.010843	0.0082	28237	789	0.027942
28	0.0006	137011	1477	0.01078	0.0082	29061	817	0.028113
29	0.0001	143008	1534	0.010727	0.0082	30230	853	0.028217
30	0.0001	149005	1589	0.010664	0.0082	31299	882	0.02818

Dynamic vs. Static

	DYNAMIC				STATIC			
Day	Alpha	Impressions	Clicks	CTR	Alpha	Impressions	Clicks	CTR
1	0.0082	1036	38	0.03668	0.0082	1036	38	0.03668
2	0.006	3850	68	0.017662	0.0082	2226	58	0.026056
3	0.0059	5874	119	0.020259	0.0082	3090	91	0.02945
4	0.005	9845	167	0.016963	0.0082	4236	120	0.028329
5	0.0048	13996	220	0.015719	0.0082	5312	143	0.02692
6	0.0046	17655	269	0.015236	0.0082	6129	168	0.027411
7	0.0043	22551	320	0.01419	0.0082	7361	197	0.026763
8	0.0042	27164	355	0.013069	0.0082	8309	216	0.025996
9	0.0043	31468	424	0.013474	0.0082	9298	255	0.027425
10	0.0039	36681	496	0.013522	0.0082	10609	298	0.028089
11	0.0036	41710	543	0.013018	0.0082	11461	322	0.028095
12	0.0035	46865	606	0.012931	0.0082	12495	354	0.028331
13	0.0033	52338	661	0.012629	0.0082	13747	393	0.028588
14	0.0032	57598	703	0.012205	0.0082	14522	409	0.028164
15	0.0032	63006	765	0.012142	0.0082	15642	445	0.028449
16	0.003	68626	810	0.011803	0.0082	16762	465	0.027741
17	0.0031	73944	863	0.011671	0.0082	17581	498	0.028326
18	0.003	79527	918	0.011543	0.0082	18763	532	0.028354
19	0.0028	85139	953	0.011193	0.0082	19775	550	0.027813
20	0.003	90515	1021	0.01128	0.0082	20731	585	0.028219
21	0.0026	96285	1070	0.011113	0.0082	21938	608	0.027714
22	0.0026	101945	1132	0.011104	0.0082	22837	636	0.02785
23	0.0023	107689	1178	0.010939	0.0082	23798	657	0.027607
24	0.0023	113529	1228	0.010817	0.0082	25054	687	0.027421
25	0.0022	119316	1271	0.010652	0.0082	25891	709	0.027384
26	0.0022	125127	1351	0.010797	0.0082	26994	752	0.027858
27	0.0013	131053	1421	0.010843	0.0082	28237	789	0.027942
28	0.0006	137011	1477	0.01078	0.0082	29061	817	0.028113
29	0.0001	143008	1534	0.010727	0.0082	30230	853	0.028217
30	0.0001	149005	1589	0.010664	0.0082	31299	882	0.02818

Dynamic vs. Static

	DYNAMIC				STATIC			
Day	Alpha	Impressions	Clicks	CTR	Alpha	Impressions	Clicks	CTR
1	0.0082	1036	38	0.03668	0.0082	1036	38	0.03668
2	0.006	3850	68	0.017662	0.0082	2226	58	0.026056
3	0.0059	5874	119	0.020259	0.0082	3090	91	0.02945
4	0.005	9845	167	0.016963	0.0082	4236	120	0.028329
5	0.0048	13996	220	0.015719	0.0082	5312	143	0.02692
6	0.0046	17655	269	0.015236	0.0082	6129	168	0.027411
7	0.0043	22551	320	0.01419	0.0082	7361	197	0.026763
8	0.0042	27164	355	0.013069	0.0082	8309	216	0.025996
9	0.0043	31468	424	0.013474	0.0082	9298	255	0.027425
10	0.0039	36681	496	0.013522	0.0082	10609	298	0.028089
11	0.0036	41710	543	0.013018	0.0082	11461	322	0.028095
12	0.0035	46865	606	0.012931	0.0082	12495	354	0.028331
13	0.0033	52338	661	0.012629	0.0082	13747	393	0.028588
14	0.0032	57598	703	0.012205	0.0082	14522	409	0.028164
15	0.0032	63006	765	0.012142	0.0082	15642	445	0.028449
16	0.003	68626	810	0.011803	0.0082	16762	465	0.027741
17	0.0031	73944	863	0.011671	0.0082	17581	498	0.028326
18	0.003	79527	918	0.011543	0.0082	18763	532	0.028354
19	0.0028	85139	953	0.011193	0.0082	19775	550	0.027813
20	0.003	90515	1021	0.01128	0.0082	20731	585	0.028219
21	0.0026	96285	1070	0.011113	0.0082	21938	608	0.027714
22	0.0026	101945	1132	0.011104	0.0082	22837	636	0.02785
23	0.0023	107689	1178	0.010939	0.0082	23798	657	0.027607
24	0.0023	113529	1228	0.010817	0.0082	25054	687	0.027421
25	0.0022	119316	1271	0.010652	0.0082	25891	709	0.027384
26	0.0022	125127	1351	0.010797	0.0082	26994	752	0.027858
27	0.0013	131053	1421	0.010843	0.0082	28237	789	0.027942
28	0.0006	137011	1477	0.01078	0.0082	29061	817	0.028113
29	0.0001	143008	1534	0.010727	0.0082	30230	853	0.028217
30	0.0001	149005	1589	0.010664	0.0082	31299	882	0.02818

Dynamic vs. Static

	DYNAMIC				STATIC			
Day	Alpha	Impressions	Clicks	CTR	Alpha	Impressions	Clicks	CTR
1	0.0082	1036	38	0.03668	0.0082	1036	38	0.03668
2	0.006	3850	68	0.017662	0.0082	2226	58	0.026056
3	0.0059	5874	119	0.020259	0.0082	3090	91	0.02945
4	0.005	9845	167	0.016963	0.0082	4236	120	0.028329
5	0.0048	13996	220	0.015719	0.0082	5312	143	0.02692
6	0.0046	17655	269	0.015236	0.0082	6129	168	0.027411
7	0.0043	22551	320	0.01419	0.0082	7361	197	0.026763
8	0.0042	27164	355	0.013069	0.0082	8309	216	0.025996
9	0.0043	31468	424	0.013474	0.0082	9298	255	0.027425
10	0.0039	36681	496	0.013522	0.0082	10609	298	0.028089
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12	0.0035	46865	606	0.012931	0.0082	12495	354	0.028331
13	0.0033	52338	661	0.012629	0.0082	13747	393	0.028588
14	0.0032	57598	703	0.012205	0.0082	14522	409	0.028164
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19	0.0028	85139	953	0.011193	0.0082	19775	550	0.027813
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27	0.0013	131053	1421	0.010843	0.0082	28237	789	0.027942
28	0.0006	137011	1477	0.01078	0.0082	29061	817	0.028113
29	0.0001	143008	1534	0.010727	0.0082	30230	853	0.028217
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29	0.0001	143008	1534	0.010727	0.0082	30230	853	0.028217
30	0.0001	149005	1589	0.010664	0.0082	31299	882	0.02818

Impact

- Implementation began in March 2010
- Increase in revenue for Chitika at the rate of about \$3,000 per day
- Based on the data collected between March 2010 and September 2010, the total increase in revenue was estimated to be in the order of \$1.2 million per year
- This revenue increase comes from Chitika being able to sign up more publishers under the Chitika Premium Program

Impact: Chitika Premium program

- Over the past year, Chitika was able to use its Premium program to partner with a very large ad aggregator in the United Kingdom
- As part of the trial process, Chitika was asked to demonstrate a click-through-rate of 0.015, or **1.5%**.
 - Our methodology was able to provide a click-through-rate of 0.0151 or **1.51%!!**
 - This accuracy won Chitika the contract and has contributed to a huge revenue increase for the company.

Impact: Chitika Select

- In December 2010, Chitika offered another service called Chitika ***Select***.
- Publishers were offered the chance to expand the usage of Chitika ads with the assurance that the expanded coverage would not come at the expense of more than 25% dilution in the click-through-rate.
 - With our solution, Chitika was able to guarantee a click-through-rate.
- The Chitika Select offering gave the firm an additional 25% boost in revenue.

Venkat Kolluri, CEO Chitika

What revenue impact did Premium have on Chitika?

“Approximately 10% boost in revenue via winbacks. That means we were able to go back to ex-customers who had tried us in the past but decided to drop us.”

“With premium we went back with a novel offer guaranteeing them that we will deliver a target click-through-rate when we choose to take an impression. This was basically an offer they couldn't refuse.”

What revenue impact did Select have on Chitika?

“Select gave us an outright 25% boost in revenue.”

What value are big publishers seeing in the solution?

“All big publishers have only one goal: diversify and grow revenue without cannibalizing their existing revenue stream (mostly from the one major player in this space: Google).”

“Our ability to guarantee a lower bound on the click-through-rate essentially gave them a risk free alternative to test out.”

What long term impact will Prophet have on Chitika?

Long term impact? The foundation stone for RTB. Period.

Impact on Other Areas of Company

- Inclusion of a conversion constraint
- Real-Time Bidding

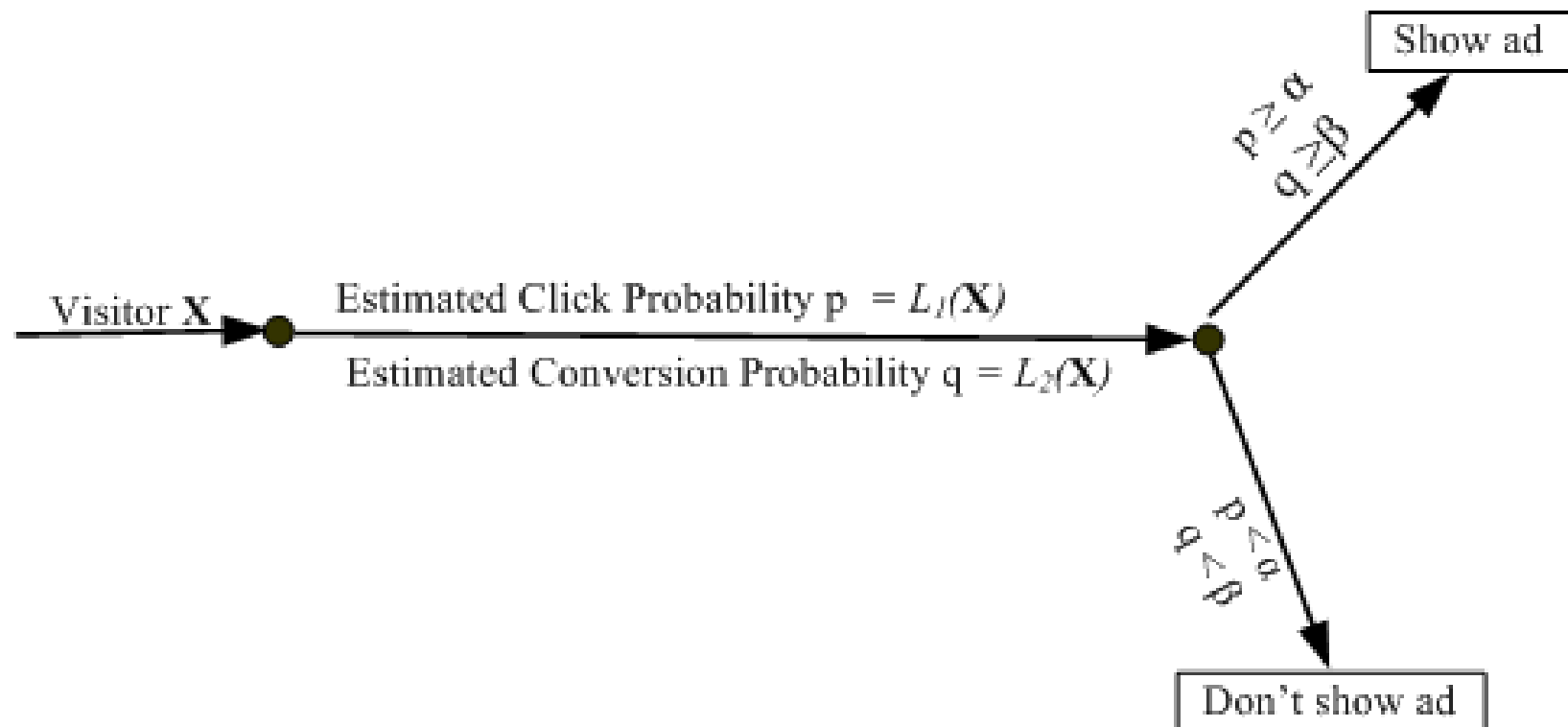
Inclusion of a Conversion Constraint



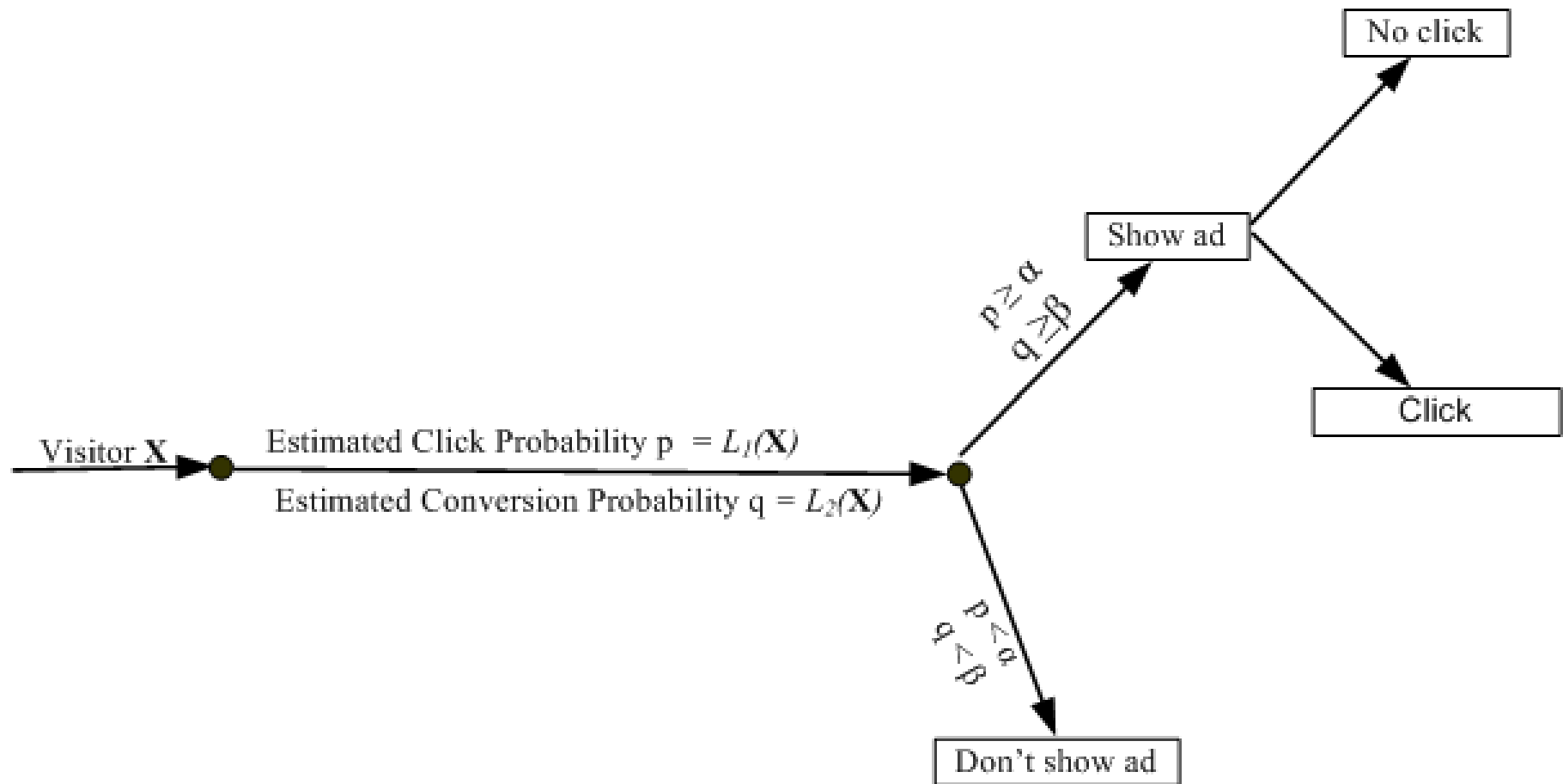
Inclusion of a Conversion Constraint



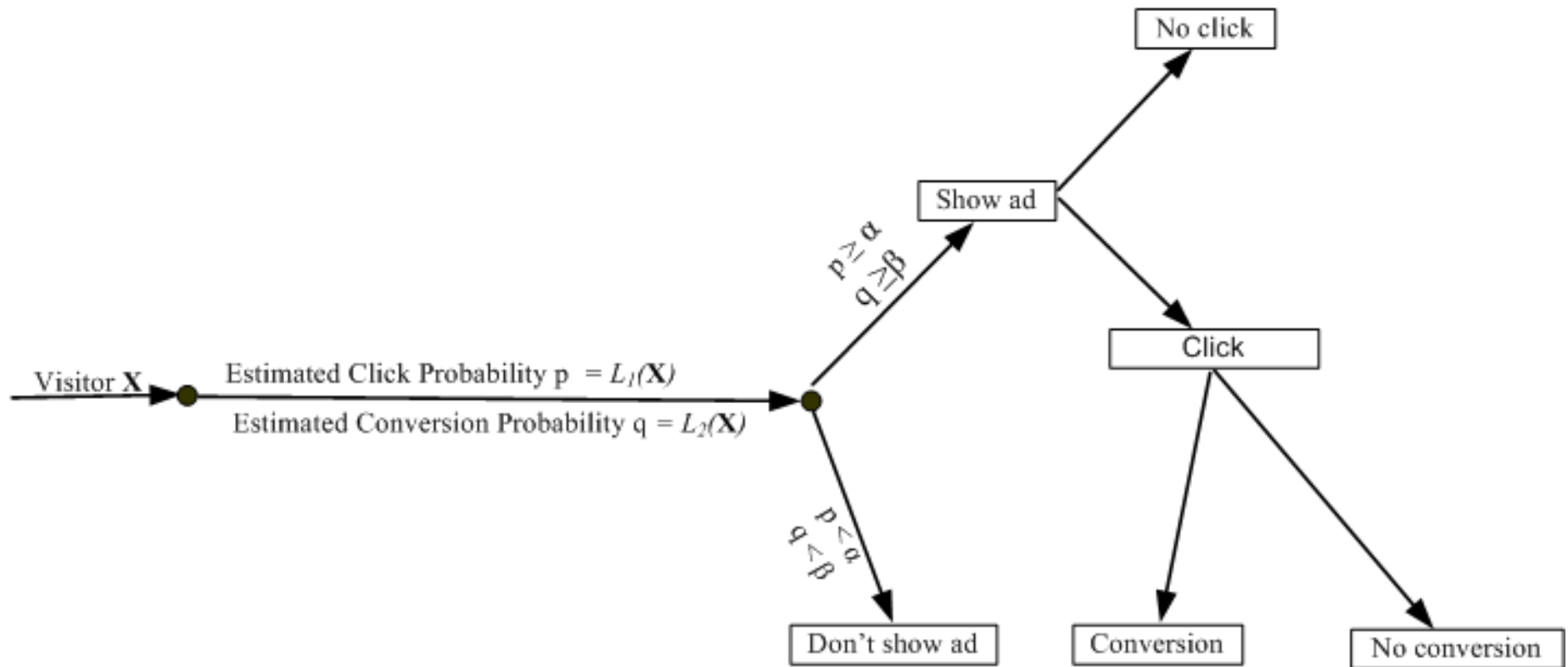
Inclusion of a Conversion Constraint



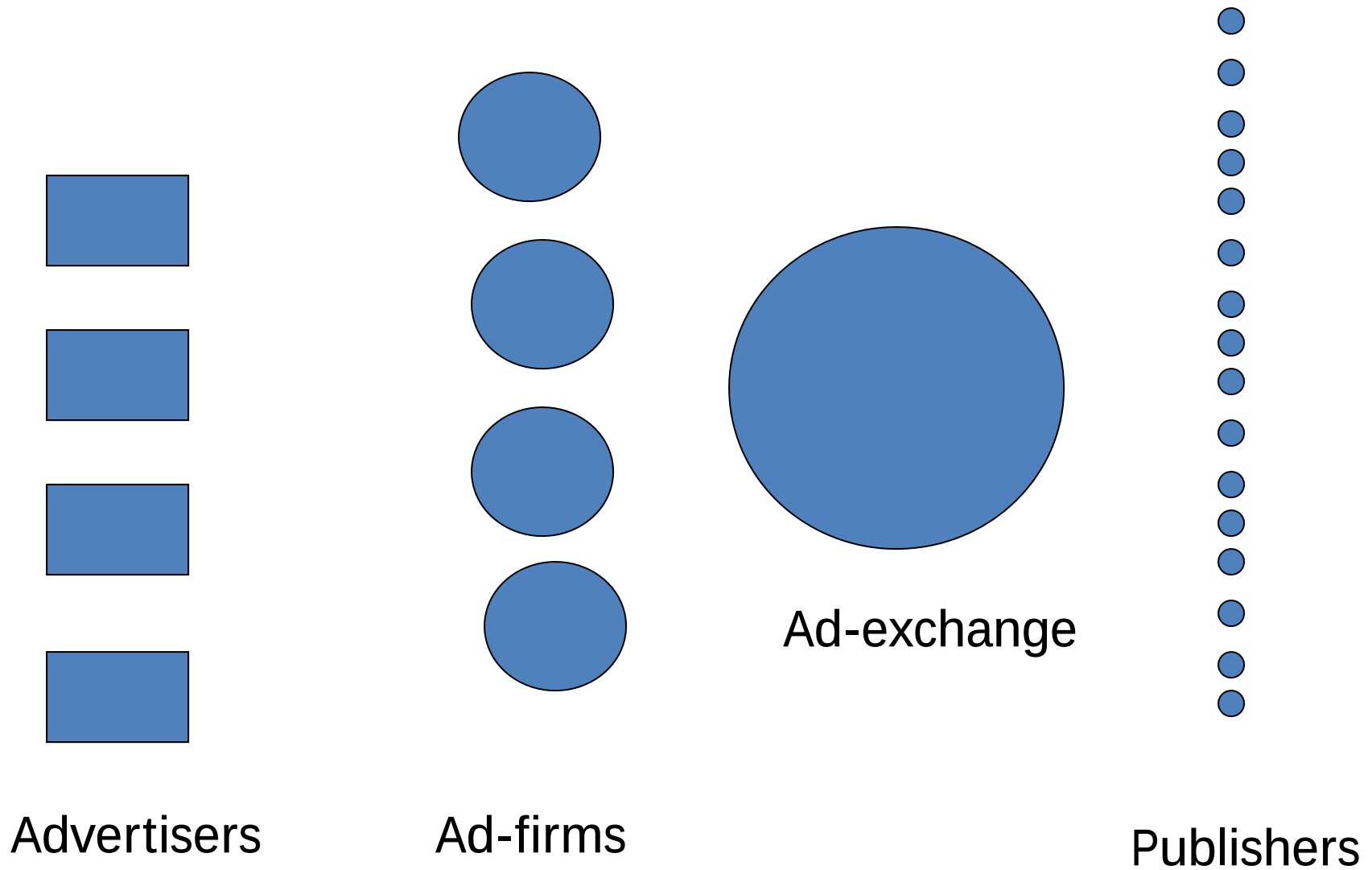
Inclusion of a Conversion Constraint



Inclusion of a Conversion Constraint



Real-time Bidding



Q & A