

Online Learning Applications

Part 6: Online advertising and auctions

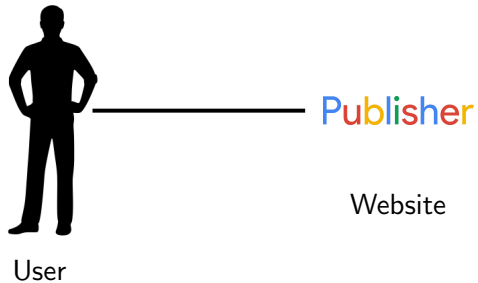
Introduction to online advertisement

Online advertisement

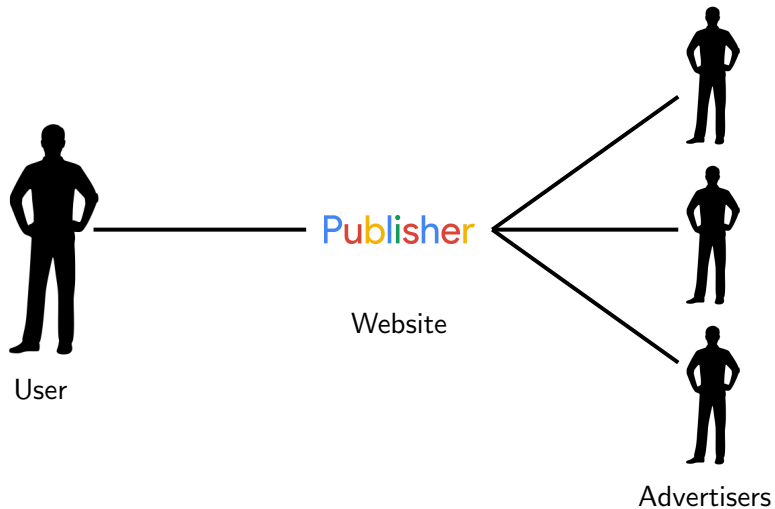


User

Online advertisement




Online advertisement



Online advertisement

- **Advertisers** want to show **ads** to users visiting a web page
- An **user** visits the web page
- The **publisher** that handles the ad **slots** on the web page assigns each slot to an advertiser

Example



computer prezzi

Tutti

Shopping

Immagini

Notizie

Maps

Altro


Impostazioni

Strumenti


Circa 84.700.000 risultati (0,32 secondi)

Guarda computer prezzi


Sponsorizzato




Acer Swift
SF114-32-C6N...
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Unieuro
Spediz. gratuita
Da Google




Hp 255 G6
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HP 1XN28EA -
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Lenovo IdeaPad
120S-14IAP BI...
270,70 €
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Da Google

Visualizza altri ...

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Trovaprezzi

In alluminio di qualità | Acquista ora Lenovo Yoga C930

[Ann.](#) www.lenovo.com/

Valutazione per lenovo.com: 3,8 ★★★★★

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FIFA 18 - PC (CIAB) · FIFA 19 - CIAB · Football Manager 2019 - PC


Example




Tutti Shopping Immagini Notizie Maps Altro Impostazioni Strumenti

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Ads

Results

Interaction

The interaction among the publisher and the advertisers goes as follows:

Interaction

- 1 An user arrives
- 2 Each advertiser **bids**
- 3 The publisher **assigns each slot** to an advertiser based on bids
- 4 The advertisers **pay** the publisher if their ad is clicked

Both advertisers and publisher have a problem to deal with.

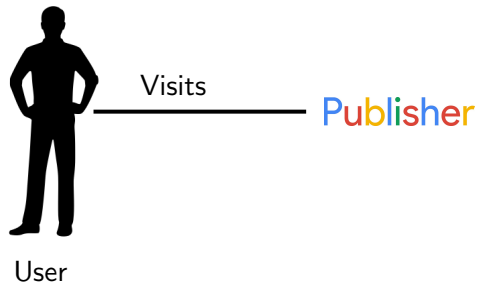
Advertiser's problem

Choose how to **bid**.

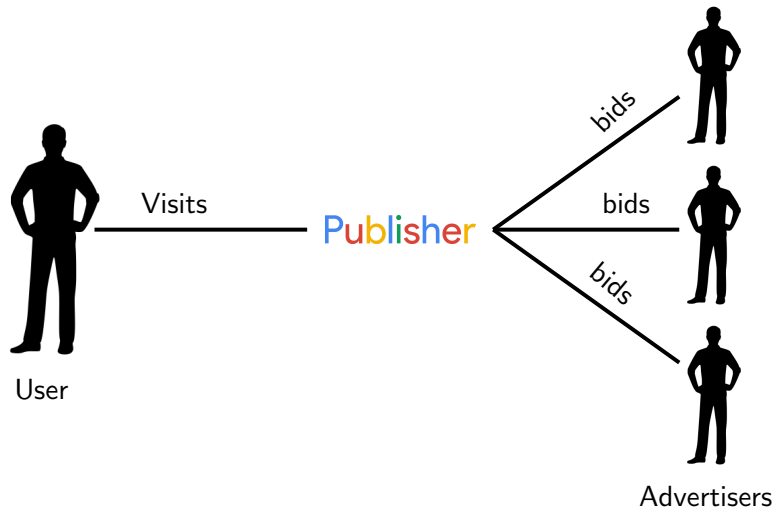
Publisher's problem

Choose how to **allocate slots** and **set payments**.

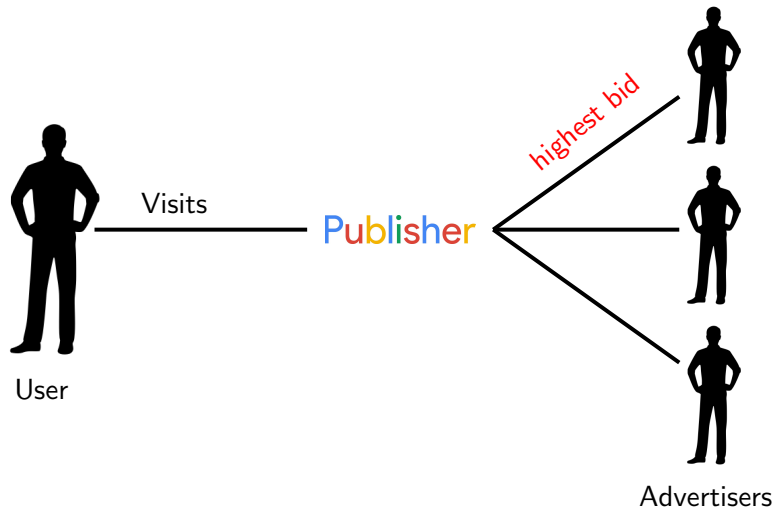
Example (single slot)



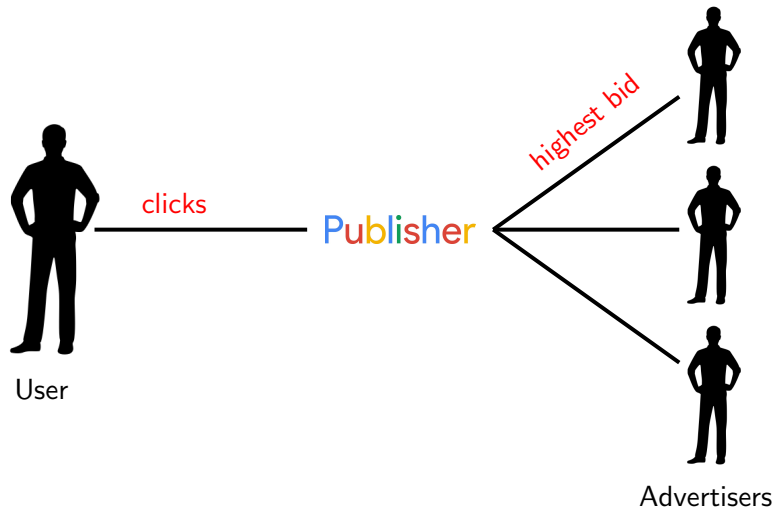
Example (single slot)



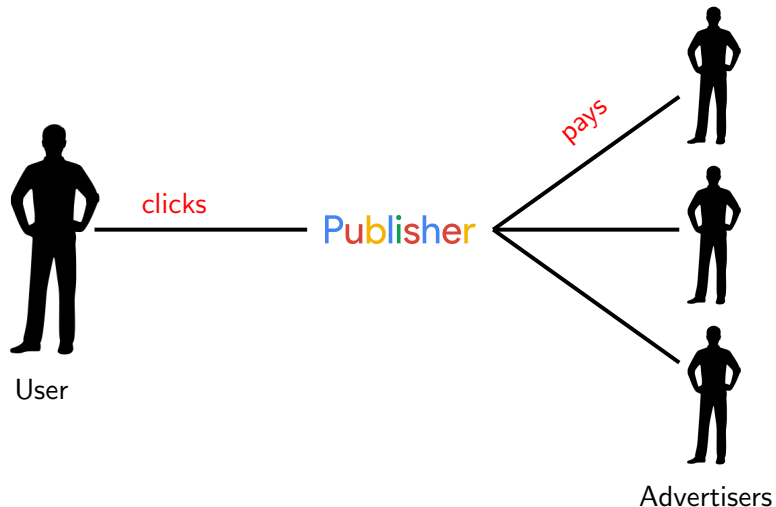
Example (single slot)





Example (single slot)



Example (single slot)



Slot prominence (some slots are better than others)




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Slot prominence (some slots are better than others)

Google









computer prezzi

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Best slot

Slot prominence (some slots are better than others)

Google









computer prezzi

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Second-best slot

Publisher's perspective

How to set payments and allocation?

The utility of an **advertiser** a for visualizing an ad on a **slot** s is:

$$\lambda_s q_a v_a$$

- λ_s is the probability that the user observes the slot (**slot prominence**)
- q_a is the advertiser's click probability given the ad has been observed by the user (**ad quality**)
- v_a is the advertiser's value per click (**ad value**)
- $\lambda_s q_a$ is the advertiser's click probability (**click trough rate**)
- $q_a v_a$ is the **expected utility** of an advertiser if the slot is observed

How to allocate slots?

Suppose that the **publisher knows all the parameters**. The optimal allocation solves:

$$\max_{s(\cdot)} \sum_a \lambda_{s(a)} q_a v_a,$$

where:

- The function $s(\cdot)$ assigns to each ad at most one slot
- If an ad is not allocated, $\lambda_{s(a)} = 0$

The optimal $s()$:

- Assigns the best slot to the ad with largest $q_a v_a$
- assigns the second-best slot to the ad with second-largest $q_a v_a$
- ...

Known and unknown parameters

$$\lambda_s \quad q_a \quad v_a$$

Known and unknown parameters

$$\boxed{\lambda_s} \quad q_a \quad v_a$$

Known and unknown parameters

$$\lambda_s \quad q_a \quad v_a$$



estimated by the publisher

Known and unknown parameters

$$\lambda_s \boxed{q_a} v_a$$

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$$\lambda_s \boxed{q_a} v_a$$

↓
estimated by the publisher

Known and unknown parameters

$$\lambda_s \quad q_a \quad \boxed{v_a}$$

Known and unknown parameters

$$\lambda_s \quad q_a \quad \boxed{v_a}$$



private information of the advertiser

Known and unknown parameters

$$\lambda_s \quad q_a \quad \boxed{v_a}$$



private information of the advertiser
use the bid instead of the valuation

How to allocate slots?

The publisher chooses the allocation solving:

$$\max_{s(\cdot)} \sum_a \lambda_{s(a)} q_a b_a,$$

where:

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Truthful auctions

Problem

The publisher uses bids as an estimation of the valuations.

Truthful auctions

Problem

The publisher uses bids as an estimation of the valuations.

Solution

Design an auction that incentivizes the advertisers to bid their valuations. This is called a **truthful auction**.

Second-price auctions

If there is only one slot, the publisher can use second-price auctions:

Second-price auction

- ▶ The advertiser a_1 with larger $q_a b_a$ wins the slot
- ▶ The advertiser pays $p_{a_1} = \frac{q_{a_2} b_{a_2}}{q_{a_1}}$ if the ad is clicked
- ▶ a_2 is the advertiser with the second largest $q_a b_a$
- The advertiser always pays $p_{a_1} \leq b_{a_1}$

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- The advertiser always pays $p_{a_1} \leq b_{a_1}$
- **The auction is truthful** → each advertiser is incentivized to report the true valuation

VCG Auctions

If there are multiple slots, the publisher can use a VCG (Vickrey-Clarke-Groves) auction.

VCG auction

- ▷ Recall that $s()$ is the allocation function that assign slots to advertisers
- ▷ Recall that $s()$ assigns slots in decreasing order of expected value
- ▷ Each advertiser a pays $p_a = \frac{1}{\lambda_{s(a)} q_a} (Y_a - X_a)$ if the ad is clicked
- ▷ $X_a = \sum_{a' \neq a} \lambda_{s(a')} q_{a'} b_{a'}$ is the utility of the other advertisers in the optimal allocation
- ▷ $Y_a = \max_{s'(\cdot)} \sum_{a' \neq a} \lambda_{s'(a')} q_{a'} b_{a'}$ is the utility of the other advertisers if a does not take part to the auction

- Each advertiser "pays" his externalizes on the other advertisers

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- Each advertiser "pays" his externalizes on the other advertisers
- **The auction is truthful \rightarrow each agent is incentivized to report the true valuation**
- If there is a single slot, VGC is equivalent to a second-price auction

First-price auctions

Truthful auctions have complex payments (see, e.g., VCG). Publishers also use **non-truthful auctions**:

- Non-truthful auctions are easier to understand
- With a single slot, the most common is the **first-price auction**

First-price auction


- ▷ The advertiser a_1 with larger $q_a b_a$ wins the slot
- ▷ The advertiser pays $p_{a_1} = b_{a_1}$ if the ad is clicked
- The winning advertiser pays exactly what they bid

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First-price auction

- ▷ The advertiser a_1 with larger $q_a b_a$ wins the slot
- ▷ The advertiser pays $p_{a_1} = b_{a_1}$ if the ad is clicked
- The winning advertiser pays exactly what they bid
-  The auction is not-truthful → the advertisers are incentivized to reduce the bid in order to decrease the payment

Non-truthful auctions

First-price auctions can be generalized to multiple slots.

Generalized first-price auction

- ▷ Each advertiser a pays $p_a = b_a$ if the ad is clicked

Non-truthful auctions

First-price auctions can be generalized to multiple slots.

Generalized first-price auction

- ▷ Each advertiser a pays $p_a = b_a$ if the ad is clicked

Other non-truthful auctions commonly used are a generalization of second-price auctions.

Generalized second-price auction

- ▷ Recall that $s()$ is the allocation function that assign slots to advertisers
- ▷ Each advertiser a pays $p_a = \frac{q_{a+1}}{q_a} b_{a+1}$ if the ad is clicked
- ▷ $a + 1$ is the ad assign to the slot just after $s(a)$

Advertiser's perspective

Bidding strategies

Now, we consider the **advertiser's perspective**

- The advertiser wants to **maximize his utility**
- An advertiser takes part to a an auction every time a new user visit the page:
 - ▷ If the auction is **truthful**, they simply **bid their valuation**
 - ▷ If the action is **not truthful**, they must **learn how to bid**

Learning to bid in non-truthful auctions

The problem of bidding in non-truthful auctions is an **online learning problem**:

- The advertiser chooses a bid at each auction $t \in [T]$
- Depending on the assumptions the setting can be adversarial or stochastic:
 - ▷ The setting is **adversarial** since the **other bidders** play unpredictably affecting the possibility of winning the auction and the payment (i.e., the reward)
 - ▷ the setting is **stochastic** if we assume that there are **lots of other bidders** and their joint behavior is stochastic

Bidding strategies

The goal of an advertiser is usually not unconstrained utility maximization.

Budget constraint

The advertisers assign a **budget** to a marketing campaign.

Problem

The advertiser must choose how to spent the budget over time.

Example of campaign:

- The advertiser tries to display the ad whenever a specific keyword is searched on a search engine.
- The advertiser stops bidding when the budget is depleted

Example



user

Publisher



Advertisers

Example



user

Publisher

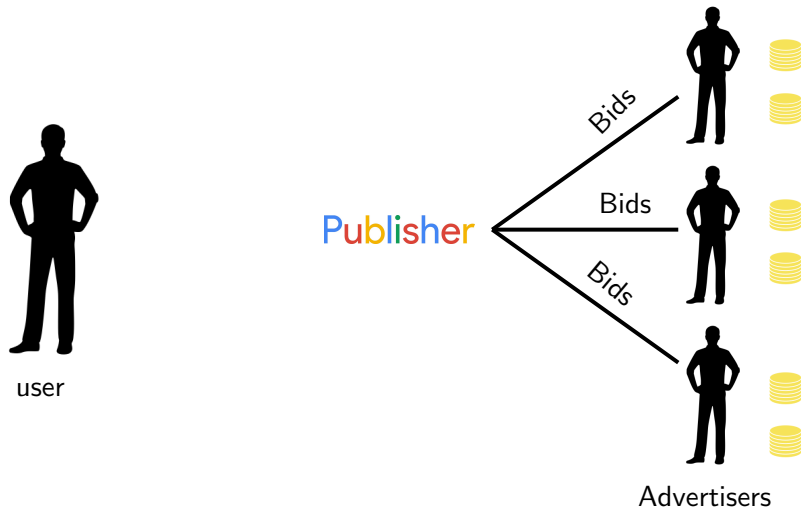


Advertisers

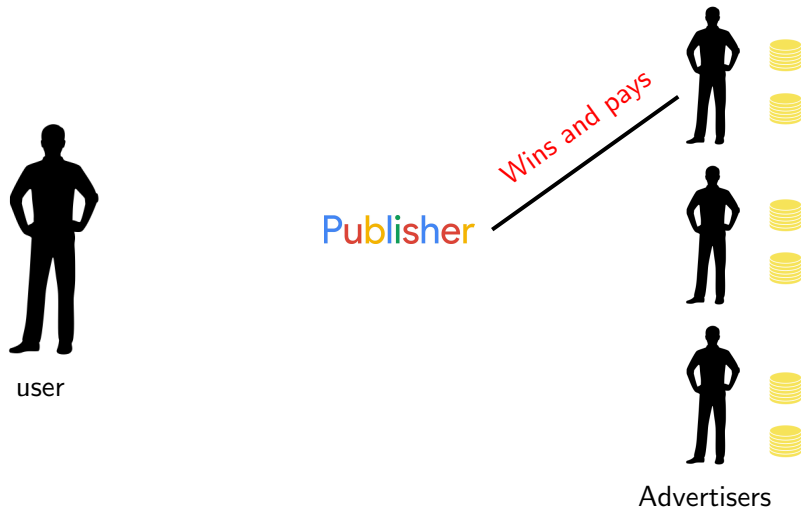
Example



Example



Example



Example



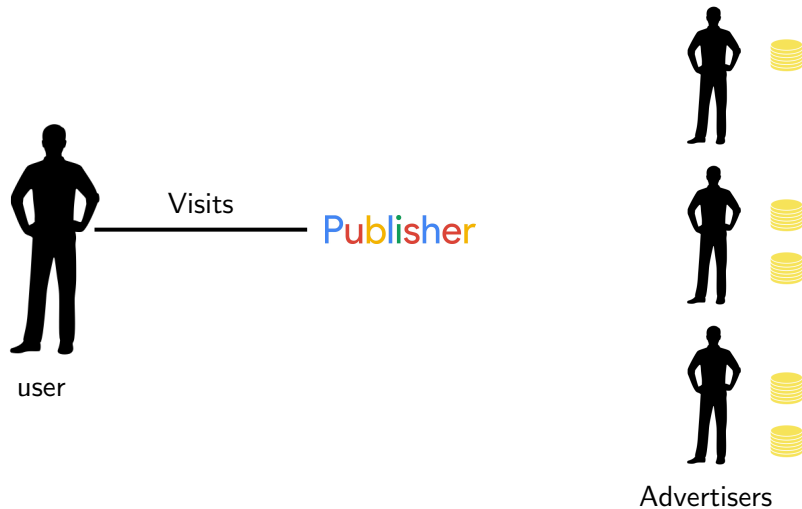
user

Publisher

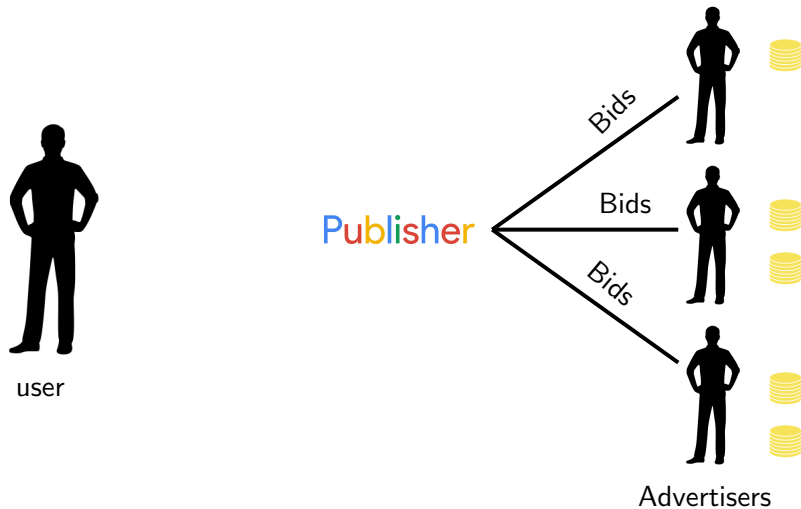


Advertisers

Example



Example



Example



Example



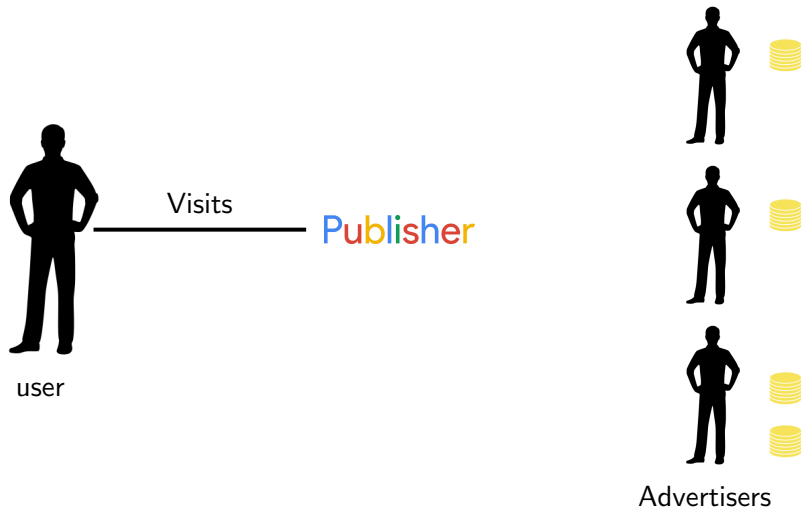
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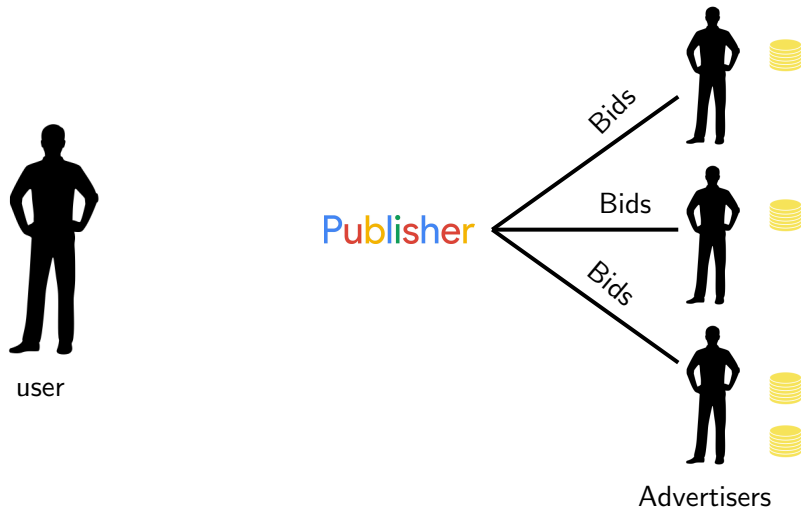


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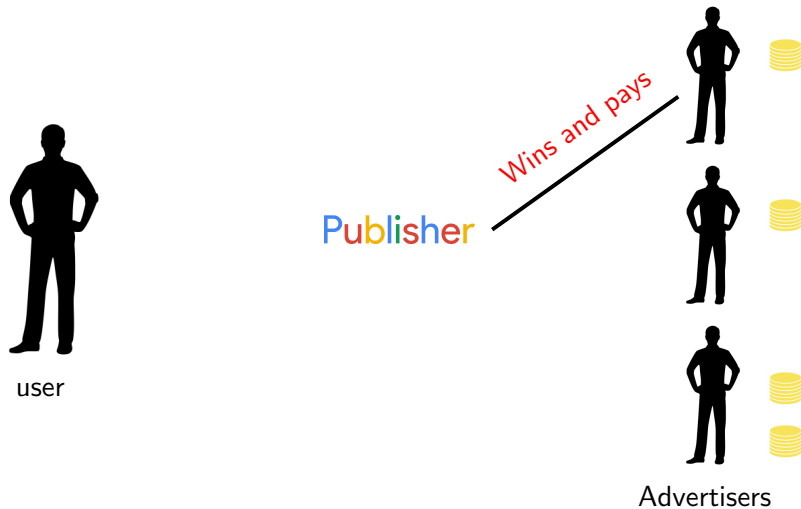
Example



Example



Example



Example



user

Publisher



Advertisers

Example



Delegation of the campaign management

- Handling this repeated bidding problem is **complex**
- Advertisers usually **delegate** this task to:
 - ▷ Ad networks
 - ▷ Publishers
 - ▷ Ad exchange
- The advertiser sets a small number of parameters and a **proxy bidder** handles the bidding.

Delegation of the campaign management

Budget & Schedule

Define how much you'd like to spend, and when you'd like your ads to appear. [Learn more.](#)

Budget ⓘ

Daily Budget ▾

\$20.00

\$20.00 USD

Actual amount spent daily may vary. ⓘ

Schedule ⓘ

☒ Run my ad set continuously starting today

☐ Set a start and end date

You'll spend no more than **\$140.00** per week.

Optimization for Ad Delivery ⓘ

Video Views ▾

Bid Amount ⓘ

☐ **Automatic** - Let Facebook set the bid that helps you get the most video views at the best price.

☒ **Manual** - Enter a bid based on what video views are worth to you.

\$4.00

per video view

Suggested bid: **\$2.30 USD** (\$1.77–\$3.26)

When You Get Charged ⓘ

10-Second Video View

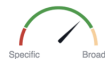
[More Options](#)

Ad Scheduling ⓘ

Run ads all the time

[More Options](#)

Audience Size



Your audience selection is fairly broad.

Potential Reach: 224,000,000 people

Estimated Daily Results

Reach

7,000 - 44,000 (of 160,000,000) ⓘ

Video Views

1,700 - 11,000 (of 32,000,000) ⓘ

The accuracy of estimates is based on factors like past campaign data, the budget you entered and market data. Numbers are provided to give you an idea of performance for your budget, but are only estimates and don't guarantee results.

[Were these estimates helpful?](#)

Proxy Bidders

Proxy bidders take in input a small number of parameter, handle the auctions, and report only aggregated results to the advertiser.

