

Content Delivery Networks in Cross-border e-Commerce

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Abstract—Cross-border e-commerce has been growing in recent years. Purchasing goods from abroad is getting easier due to global deliveries, well-known payment methods and decreasing language barriers. Content Delivery Network (CDN) is a technical solution. Deploying CDN for cross-border e-commerce can improve performance and consumer experience. In this paper, four sets of cross-border online stores, containing together 57 e-commerce stores, are examined. Each set is a group of online stores operating in many European markets with different Domain Name System (DNS) settings. Two sets use Cloudflare CDN and its DNS server. Other two sets use country DNS server settings without CDN. Results show that DNS lookup time significantly decrease for cross-border users when online stores are using a CDN, improving overall website time load. Increase of speed for resolving domain names is on average from 40ms to 5ms. No significant improvement was observed for user in the same country location.

Keywords—e-Commerce; cross-border e-commerce; content delivery networks; DNS lookup time; time to first byte

I. INTRODUCTION

Cross-border e-commerce (CBEC) is a type of trade between retailers and customers, in which retailers sell goods online using an e-commerce store. Retailers selling online are called e-tailers. Customers purchase goods using a web browser on their computers or mobile devices. As the online stores and customers are from two different countries, the orders need to be sent from one country to another country, thus crossing a border [1]. This definition is applicable in the European Union (EU) [2], whereas in China cross-border e-commerce is often considered as trade between different areas like North China and South China, or pilot areas [3].

One of the key factors in e-commerce influencing conversion rate in an online store is speed of its website [4]. When the response time increases, it is negatively influencing the conversion rate. Shorter response time and overall faster site speed positively influence the conversion rate. Problem of website load time is complex [5]. There is no single factor that decides how fast a website will load. Load time depends on three main areas. First, the server prepares data which will be sent to the online visitor. Second, there is a transmission or download between server and online visitor. Third, the software used for rendering incoming data, usually a web browser, needs time to render the whole website and show it to the online visitor. Each area can be optimized in its own way.

First, the server response time is influenced by time to first byte (TTFB) [6], Content Delivery Networks [7], disk caching [8], keep alive [9], HTTP/2 [10], code acceleration, varnish/caching [11], accelerated mobile pages [12], etc. Second, the download time (transmission) is influenced by size of image files [13], the proper type of image files [14], (e.g. using the JPG for pictures instead of PNG), minification of text objects like JavaScript scripts, CSS files and HTML files, HTTP compression [15], header expiration date [16], CSS sprites [17], image scaling for mobile screens [18], cookie-less domain [19], etc. Third, the rendering time is influenced by proper order of loaded CSS files and JS scripts [16], parallel connection [20], HTML optimization [21], lazy load for images [22], DNS prefetch [23], prerender and prefetch of files and URLs [24], CSS optimization [25], JS optimization [26], etc.

Cross-border e-commerce mainly exists in long range distances, at least from one country to another country when EU area is considered. The same is for online store visitors, when they browse e-commerce from another country. Data that needs to be sent from server to online visitor needs to be sent for a long distance. This influences negatively the website load time. The longer the distance between an online store and its customer, the longer the website load time. Usually server of an online store is located in the same country where most online customers of this store live. Cross-border e-commerce expands distances between data servers and customers that is why they are located further than before. Load time is slower compared to the load time of an online store located closer to the customer. Based on this analysis a research question is formulated:

RQ: What are the ways of increasing website load time in cross-border e-commerce?

The goal of this paper is to hypothesize that using content delivery network, – a factor that influences server response time and DNS lookup time, – can decrease load time in cross-border e-commerce. The rest of this paper is organized as follows. In the next section, a review of the relevant literature is undertaken. Then the study setup and hypothesis development are described and, following this, the results are presented and discussed. Finally, conclusions are drawn.

II. LITERATURE REVIEW

A. Content Delivery Networks

The content delivery networks (CDNs) technique is one of the successful virtual networks rapidly developed over the last two decades with the specific advantage of optimizing the Internet. Nowadays, the CDN has become one of the most important parts of the Internet architecture for content distribution.

One direction is to show how CDNs has positively influenced business and companies. CDNs improve network performance and offer fast and reliable applications and services by distributing content to cache servers located close to users. It is a method for reducing response times experienced by Internet users through locating multiple servers close to clients. CDNs act as trusted overlay networks that offer high-performance delivery of common Web objects, static data, and rich multimedia content by distributing the content load among servers that are close to the clients. CDN benefits include reduced origin server load, reduced latency for end users, and increased throughput [7].

Content delivery networks are taking into account different variables such as caching hit ratios, network latency, number of surrogates, and server capacity [27]. Main research areas in the field of CDN are pointing out the motivations, analyzing the existing strategies for replica placement and management, server measurement, best fit replica selection and request redirection [28]. CDN is a payable service. Different service type architectures for CDNs are available together with proposed pricing schemes to complement this architecture and provide fair service to the subscribed publishers [29]. There is a need of a balance between the costs for web content providers and the quality of service for web customers in terms of CDNs [30].

Another direction is to improve the existing network solutions and build new architecture and solutions for CDNs. The innovative technologies in CDNs are highlighted and their evolution triggered by ever newer emerging applications is presented. By presenting an in-depth discussion about the architecture, challenges, and applications of CDNs, their importance for the future Internet is demonstrated [31]. In CDNs predictive content distribution strategies are inspired by methods developed in the recommender systems area. Different content placement strategies are outlined based on the observed user consumption patterns and their applicability in the state of the art CDNs [32]. Cloud-based CDNs take advantage of the geographical availability and the pay-as-you-go model of cloud platforms [33].

Thoroughly understanding the CDN industry from different aspects including market choice, technology, performance, tendency and infrastructure is indispensable to future Internet. Comprehensive studies on challenges to the existing commercial CDNs are provided [34]. Different CDN architectures have different relative strengths and weaknesses. The role of location, the growing complexity of the CDN ecosystem, and their relationship to and implications for interconnection markets is highlighted [35].

B. Cross-Border e-Commerce

CBEC is strongly developing in China. One area of works is to analyze how logistics in CBEC works in China. With the rapid development of cross-border e-commerce, the demand for and importance of cross-border logistics service also increase [36]. A review of different 32 studies on how CBEC logistics work in China was made by Giuffrida et al. [37]. They identified a set of possible development areas, including distribution network design, i.e. deciding how to shape the CBEC distribution structure, and logistics outsourcing, i.e. determining whether to manage logistics activities in-house or through third parties. The impact of cross-border e-commerce on international trade in the context of China is investigated, mainly from the perspective of transaction cost economics in conjunction with the traditional comparative advantage model by analyzing information cost, negotiation cost, transportation cost, tariffs and middlemen cost separately [38].

Three types of supply chain localization in cross-border e-commerce for export markets (sales, warehousing, and R&D localization) are identified. The three localization strategies serve as the driving force and the main business model innovation in cross-border e-commerce [39]. China's e-commerce cross-border logistics main modes are: international postal packet, international express, overseas warehouse, cross-border logistics, third party logistics, bonded zone and free trade zone, etc., however, CBEC logistics is not yet developed as well like CBEC [40].

Other issues concerning Chinese CBEC are described in different works. Cross-border e-commerce should include some mechanisms of government policies [41]. Chinese CBEC businesses can be focused more on the service and cost control of supply chain downstream through strategic cost control measures [42]. Traditional e-commerce recommender system is not suitable for the CBEC situation, thus there is a need of a personalized e-commerce recommender system to meet the needs of cross border e-commerce [43].

CBEC industry in China generally presents a tendency of solid growth; it has had a relatively stable situation for logistics facilitation but a drastic fluctuation in customs facilitation, has gradually shifted to competing for cheaper and more efficient marketing techniques as well as channels, and has experienced a remarkable amelioration of risk magnitude [44]. The relationship between technological progress, cross-border e-commerce and the establishment of global digital customs can be explored from the dimensions of the latest development of new digital infrastructure [45]. Customer satisfaction index system in cross-border e-commerce was constructed which follow the principle of objectivity, comprehensiveness and dynamic [46] and a model of consumer behavior was created after incident in well-known Chinese market place which operates on cross-border market [47].

Outside China different aspects of CBEC have already been described. Barriers in cross-border e-commerce between USA and Canada in duty regimes and tax laws have been studied [48]. A conception of an integrator in cross-border e-commerce was proposed and its main task is to integrate the whole supply chain [49]. Different characteristics like gender, education, computer skills, nationality and trust in reviews positively

influence the CBEC [50]. A novel platform architecture to improve the pluggability of e-commerce services was proposed and checked on the example of a trade compliance service for cross-border retail [51]. Study on cross-border e-commerce in European environment and description of its current status emphasise how e-tailers should be prepared for sustainable cross-border e-commerce in the EU [52].

III. MATERIALS AND METHODS

This section contains research method and hypotheses development. Research method is constructed from four different tests, which will support or not the stated hypotheses.

The subject for this study are the four sets of cross-border online stores. Each set is owned by one company. The first set of 8 online stores is owned by Babyaisle, a Polish company which sells goods for babies and kids in online stores. Detailed information of countries and languages of this set is in Table I. The second set of 16 online stores is owned by Eobuwie, a Polish company selling shoes, accessories and handbags in online stores. Detailed information of countries and languages of this set is in Table II. The third set of 18 online stores is owned by Oponeo, a Polish company that sells tires in online stores. Detailed information of countries and languages of this set is in Table III. The fourth set of 15 online stores is owned by Babymarkt, a German company selling goods for babies and kids in online stores. Detailed information of countries and languages of this set is in Table IV. After launching an online store for national market, the owner of each set decided to create an offer for foreign customers by launching the same store in another language and country versions.

There are two different approaches for launching another language and country version. The new language and country version can be launched in a subdirectory of a main domain name. Usually it is observed for well-known global brands which have “.com” domain names and the version of an online store is localized in a subfolder. The second approach, used in this case, is to run each language and country version in separate country-coded top-level domain.

Store owners have launched a copy version of its online store but have localized for different countries. For each set, an e-commerce engine, backend engine and database are the same for every language and country version. However, frontend emulates different languages and localized country versions. By localization it means currency conversion, IP detection for delivery purpose and different sets of reviews and opinions given by consumers from each targeted country. These four sets of online stores now have different configurations in terms of using CDNs. Specific configuration is shown in Tables I to IV.

Three tools will be used to measure DNS lookup time, connect time and time-to-first-byte in different sets. DNS lookup time measurement is the time spent resolving the DNS name to an IP address. Typically, this is measured from a DNS server located near the client that wants to communicate with a server [53]. Connection time measurement is the time required for setting up a connection from a client to a Web server. This delay is the time needed to establish the connection [53]. Time-to-first-byte measurement is the amount of time from when the

client sends the request (GET command) until it sees the first byte back from the server. This is a single round trip across the Internet [53].

First is the DNSPerf [https://www.dnsperf.com/] which is DNS performance analytics and comparison tool. This tool will show speed results of DNS lookup time for different online store versions. DNSs will be queried from different geographical locations.

The second tool is a script written for unix systems using the *dig* command. The script will be programmed to test simultaneously the end-client speed for resolving DNS names. The code is based on [54] proposition. The second test will be repeated 24 times, for each local DNS available for country-coded top-level domain (ccTLD). Unfortunately, domain suffix “.eu” and “.com” are not country coded – the first represents all EU area and the second is a generic domain. There is no specific DNSs for “.eu” or “.com”.

The third tool is a *curl* command deployed under unix/macos terminal service. Command is configured to measure the lookup time, connect time and time-to-first-byte. Important value to pay attention is the time-to-first-byte [6], which informs how long it took for the content to be sent back to browser to start processing the page. The code is based on [55] proposition. This tool will show the lookup time, connect time and time-to-first-byte. The fourth test will be repeated for each online store from one geographical location – the author’s location.

Based on this research method two hypotheses are proposed:

H1. Deploying e-commerce on CDN will decrease DNS lookup time in localized e-markets for cross-border visitors.

H2. Deploying e-commerce on CDN will decrease time-to-first-byte value in localized e-markets for cross-border visitors.

TABLE I. LOCALIZED VERSIONS OF BABY AISLE ONLINE STORES

Domain name	Targeted country	Language	CDN
babyland.pl	Poland	Polish	CloudFlare
babyaisle.de	Germany	German	CloudFlare
babyaisle.dk	Denmark	Danish	CloudFlare
babyaisle.eu	Other EU countries	English	CloudFlare
babyaisle.fr	France	French	CloudFlare
babyaisle.es	Spain	Spanish	none
babyaisle.it	Italy	Italian	none
babyaisle.cz	Czech Republic	Czech	none

Data contains the four sets of online stores. For each set, usually a store in each particular country is set up with the core domain name, reflecting name of the company or brand. Core names are babyland, oponeo and pinkorblue. Eobuwie for each country has launched an online store with local translation of “efootwear”. First set for Babyland contains 8 online stores.

In Table I there is a summary of the current configuration for each localized version in the first set. From a set of eight domain names, five (.pl, .de, .dk, .eu, and .fr) are using CDN from CloudFlare [https://www.cloudflare.com/]. Currently CloudFlare is served for more than 13 million domain names and has 165 data center locations. Three domain names are not using CDNs. They are hosted in Oktawave, Polish public cloud service.

To use CDN from CloudFlare a domain name must set for their DNS names. During configuration of the CloudFlare service, it shows to which DNSs it should be set. CloudFlare (CF) is a well-recognized CDN, DNS, DDoS protection and security service. Switching domain name into CF it allows measuring changes in DNS speed resolving and load time for a website.

In Table II, a summary of the current configuration for each localized version in the second set is presented. In this set all of the 16 online stores from Eobuwie owner are using CDN from CloudFlare.

TABLE II. LOCALIZED VERSIONS OF EOBUWIE ONLINE STORES

Domain name	Targeted country	Language	CDN
eobuwie.com.pl	Poland	Polish	CloudFlare
eschuhe.de	Germany	German	CloudFlare
eobuv.com.ua	Ukraine	Ukrainian	CloudFlare
efootwear.eu	Other EU countries	English	CloudFlare
chaussures.fr	France	French	CloudFlare
zapatos.es	Spain	Spanish	CloudFlare
escarpe.it	Italy	Italian	CloudFlare
eobuv.cz	Czech Republic	Czech	CloudFlare
ecipo.hu	Hungary	Hungarian	CloudFlare
eobuv.com	Russia	Russian	CloudFlare
eobuv.sk	Slovakia	Slovakian	CloudFlare
eavalyn.lt	Lithuania	Lithuanian	CloudFlare
epantofi.ro	Romania	Romanian	CloudFlare
eskor.se	Sweden	Swedish	CloudFlare
epapoutsia.gr	Greece	Greek	CloudFlare
obuvki.bg	Bulgarian	Bulgarian	CloudFlare

TABLE III. LOCALIZED VERSIONS OF OPONEO ONLINE STORES

Domain name	Targeted country	Language	CDN
oponeo.pl	Poland	Polish	none
oponeo.de	Germany	German	none
oponeo.sk	Slovakia	Slovak	none
oponeo.co.uk	United Kingdom	English	none
oponeo.fr	France	French	none
oponeo.es	Spain	Spanish	none
oponeo.it	Italy	Italian	none
oponeo.cz	Czech Republic	Czech	none
oponeo.hu	Hungary	Hungarian	none
oponeo.ch	Switzerland	German	none
oponeo.com	United States	English	none
oponeo.ie	Ireland	Irish	none
oponeo.nl	The Netherlands	Dutch	none
oponeo.at	Austria	German	none
oponeo.com.tr	Turkey	Turkish	none
pneus-oponeo.ch	Switzerland	French	none
pneus-oponeo.be	Belgium	French	none
banden-oponeo.be	Belgium	Dutch	none

In Table III there is a summary of the current configuration for each localized version in the third set. In this set all of the 18 online stores from Oponeo owner are using own DNS based on the Polish domain name and are not using any CDNs. Oponeo has two language versions of online stores for Switzerland (German and French) and two language versions for Belgium (French and Dutch).

Table IV contains a summary of the current configuration for each localized version in fourth set. In this set all of the 15 online stores from Babymarkt owner are using own DNS based on German domain name and are not using any CDNs.

TABLE IV. LOCALIZED VERSIONS OF BABYMARKT ONLINE STORES

Domain name	Targeted country	Language	CDN
pinkorblue.pl	Poland	Polish	none
babymarkt.de	Germany	German	none
pinkorblue.dk	Denmark	Danish	none
baby-markt.com	Other EU countries	English	none
roseoubleu.fr	France	French	none
rosaoazul.es	Spain	Spanish	none
pinkorblue.it	Italy	Italian	none
pinkorblue.cz	Czech Republic	Czech	none
baby-markt.at	Austria	German	none
baby-markt.ch	Switzerland	German	none
pinkorblue.be	Belgium	Dutch	none
pinkorblue.fi	Finland	Finnish	none
pinkorblue.nl	The Netherlands	Dutch	none
pinkorblue.no	Norway	Norwegian	none
pinkorblue.se	Sweden	Swedish	none

IV. RESULTS

In the first test done in DNSPerf, each domain name was checked from 50 different locations across Europe. Fig. 1 presents results in boxplot for DNS response times for every location for each online store in each set.

Brief results from the first test show that DNS lookup time for domains using CloudFlare DNSs is faster than for the domains not using it. Detailed boxplot statistics are in Table V.

The second test is done by using console window with the terminal. The test checks how fast for local client were the DNSs. The author used this script to do the test.

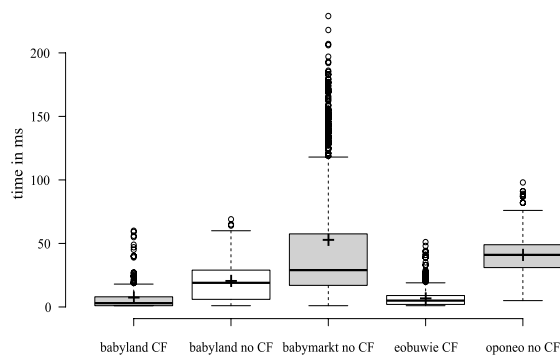


Fig. 1. Boxplot Results for Each Set of Online Stores. Babyaisle is Divided into Two Metrics, one with CF, the Second – without CF.

TABLE V. BOXPLOT STATISTICS FOR DNS LOOKUP TIME

	babyland CF	babyland no CF	babymarkt	eobuwi e	oponeo
Upper whisker	18.00	60.00	118.00	19.00	76.00
3rd quartile	8.00	29.00	57.50	9.00	49.00
Median	3.00	19.00	29.00	5.00	41.00
1st quartile	1.00	6.00	17.00	2.00	31.00
Lower whisker	1.00	1.00	1.00	1.00	5.00
Nr. of data points	249.00	147.00	744.00	850.00	886.00
Mean	7.39	20.42	52.78	6.68	40.91

```
for domain in babyaisle.es babyaisle.it babyaisle.cz
babyaisle.de babyaisle.dk babyaisle.fr babyaisle.eu
babyland.pl; do \
```

```
custom_dns=$(dig @custom-IP ${domain} / awk
'msec/{print $4}');\
```

```
cloudflare_dns=$(dig @1.1.1.1 ${domain} / awk
'msec/{print $4}');\
```

```
printf "%${domain}\tCloudFlare\tDNS
${cloudflare_dns}ms\tCustom DNS ${custom_dns}ms\n";\
```

done

TABLE VI. ccTLD CUSTOM DNS VS CLOUDFLARE DNS FROM AUTHOR'S ORIGIN LOCATION (PL)

No.	ccTLD	DNS IP	Domain name	CloudFlare DNS	Custom DNS
1	ES	80.66.120.34	babyaisle.es	48ms	113ms
2	IT	87.241.40.194	babyaisle.it	46ms	101ms
3	CZ	81.30.229.149	babyaisle.cz	44ms	100ms
4	DE	62.8.159.193	babyaisle.de	46ms	81ms
5	DK	195.137.178.10	babyaisle.dk	46ms	63ms
6	FR	80.14.75.5	babyaisle.fr	44ms	137ms
7	PL	212.87.229.67	babyland.pl	47ms	45ms
8	UA	91.211.213.10	eobuv.com.ua	48ms	133ms
9	LT	86.38.173.114	eavalyn.lt	52ms	86ms
10	RO	195.189.150.37	epantofi.ro	52ms	140ms
11	SE	85.30.174.198	eskor.se	47ms	142ms
12	GR	195.130.67.4	epapoutsia.gr	48ms	154ms
13	BG	195.234.236.34	obuvki.bg	55ms	156ms
14	HU	91.83.165.219	oponeo.hu	48ms	151ms
15	CH	62.202.3.102	oponeo.ch	48ms	98ms
16	SK	92.240.244.8	oponeo.sk	48ms	123ms
17	TR	213.128.64.149	oponeo.com.tr	49ms	155ms
18	UK	95.172.66.6	oponeo.co.uk	55ms	118ms
19	IE	86.43.81.177	oponeo.ie	47ms	134ms
20	NL	145.131.137.117	pinkorblue.nl	48ms	151ms
21	AT	188.118.227.21	baby-markt.at	48ms	119ms
22	BE	91.183.58.171	pinkorblue.be	47ms	152ms
23	FI	83.102.69.175	pinkorblue.fi	49ms	147ms
24	NO	141.0.79.138	pinkorblue.no	52ms	168ms

The first line defines domain names to check. This script was launched four times, for each set in this study. The version presented above is prepared for the first set of online stores. The second line checks with *dig* command custom DNS. In Table VI there is a list of local DNSs for each ccTLD in all four sets. List of publicly available DNS by country is at <https://public-dns.info>. For the test one DNS was chosen for each ccTLD – the one that was first on the list. Being first means that it was recently checked and was valid. The third line checks CloudFlare DNS, and the fourth line prints the results on the screen.

The goal of this test is to create a reversed route from the author's origin location (PL) to DNS in another country. It will emulate the same behavior when an online visitor from one country is connecting to an online store from another. Additionally, for comparison, the script is checking connection time for CloudFlare DNS.

The third test is done by script based on *curl* command. The script is checking how fast the first byte is sent from server to user and what is the time-to-first-byte. This script is similar to the one mentioned above. The code lines are the following:

```
for domain in $domain_list; do \  
    ttfb=$(curl -o /dev/null -s -w \  
"Lookup:\t%{time_namelookup}\tConnect:\t%{time_connect}\t\  
TTFB:\t%{time_starttransfer}\tCode:\t%{response_code}\tIP:\t\  
%{remote_ip} \n" https://${domain});\  
    printf "${domain}\t ${ttfb} \n" >> list.txt;\  
done
```

Curl is using one location for this test – the one where the computer is connected. Variables measured via *curl* are:

- `%{time_namelookup}` – shows the time (in seconds) it took from the start until the name resolving was completed. This is considered as lookup time.
- `%{time_connect}` – shows the time (in seconds) it took from the start until the TCP connect to the remote host (or proxy) was completed. This is considered as connect time.
- `%{time_starttransfer}` – shows the time (in seconds) it took from the start until the first byte was just about to be transferred. This is considered as time-to-first-byte (TTFB).

In Appendix all 57 domains from four sets are listed, with lookup time, connect time, TTFB times for each domain name, together with the current IP address.

V. DISCUSSION

Results showed that the proposed method for improving website load time positively works for the DNS lookup time. For the tests the author took respectively 8, 16, 18, and 15 similar domain names belonging to four different owners. Each domain is an online store targeted for specific European market.

Results, given by DNSPerf, revealed that setting DNS from CloudFlare significantly improved DNS lookup time. DNS

lookup time for domains using CF was, on average, 4 times faster for Babyaisle online stores belonging to the first set, comparing to the other online stores from this set, not using CF. Average DNS lookup time for domains on CF was 7.39 ms whereas the average time for domains on `dns.home.pl` was 20.32 ms. In the second set, an average DNS lookup time for Eobuwie, where all of them are located in CF DNS, is 6.68 ms. In the third set, an average DNS lookup time for Oponeo, for the online stores not using CF or any other CDN, is 40.91 ms. In the fourth set, average DNS lookup time for Babymarkt, for the online stores not using CF or any other CDN, is 52.78 ms.

Results, given by script using *dig* command, revealed that setting DNS from CF significantly improved DNS lookup time from the client point of view. DNS lookup time for each domain, except “.pl”, using CF was, on average, 2 to 3 times faster than for the domain set and its localized DNS. Average time for domains on CF using *dig* script was 48.4 ms whereas the average time for the domain and its localized DNS was 123.6 ms. Results for “.pl” domain were at each trial almost identical – around 46 ms. This is because the tested “.pl” domain is in the same country where all the tests took place. Results given by DNSPerf and the *dig* command support first hypothesis: Deploying e-commerce on CDN will decrease DNS lookup time in localized e-markets for cross-border visitors.

The third test with the use of *curl* command does not support the second hypothesis. This is because of two reasons. First, the test was run from one computer in one geographical location, however, results, even for online stores in the same set were different in terms of the lookup time, connect time and time-to-first-byte. The expectation was that online stores with the same configuration, location and backend engine would show similar results. This could be affected by testing real, living websites. Online load is different during the day and has some rise and falls depending on number of actual online visitors, and there are many other factors that influence the network performance and website load times. Some of them are mentioned in the introduction section.

Second, the average value of TTFB for each set is different. For Babyaisle is 1484 ms, for Eobuwie is 407 ms, for Oponeo is 729 ms and for Babymarkt is 567 ms. It shows that TTFB strongly depends on backend engine and server configuration, instead of DNS setting and using CF. For instance, Babyaisle is using CF and has the fastest DNS lookup times, whereas its TTFB is the lowest from all four sets.

A. Contributions

In recent years, online transactions in cross-border e-commerce have become an essential part of the European e-market and have shown great potential. Because of some uncertainty in cross-border e-commerce, customers search for factors that can reduce the risk of buying cross-border. Online store owners can show that they recognize and carefully treat customers from abroad. This study empirically explored two factors that could improve website load time in cross-border e-commerce. There are two main findings. First, there are DNSs which have different lookup time. Lower lookup time means faster response. CloudFlare seems to be the fastest DNS service that can be used for cross-border e-commerce. Second,

the time-to-first-byte is a metric that has different results for each online store. Curl shows detailed scores for this metric in seconds, but these results prove that time-to-first-byte strongly depends on e-commerce engine and server configuration. These findings have significant theoretical and practical implications.

This research can contribute to the literature on e-commerce behavior. Contribution relates to the consumer experience. If a consumer experiences faster load time for online store, it positively influences his readiness for making transactions. The results of the study suggest using faster DNS for cross-border e-commerce. In cross-border e-commerce, except shipment to another country, different language and currency, there is website load time factor, which can be taken into consideration when the online store goes to cross-border trade.

From the point of view of sustainability, this approach decreases usage of internet network. Customer only needs to connect to the closest network node for resolving DNS. Network load is lower and eventually the network traffic is sustainable.

B. Practical Implications

This study also yields several direct managerial implications. First, online stores have possibility to improve site performance in specific circumstances for cross-border e-commerce. This can be improved by starting using CDN service. Usually this kind of service is easy to launch, and costs are reasonable. Second, research method shows that this approach only works for online visitors from other countries. Test results using dig command revealed that using CDN in the same country does not influence DNS lookup time significantly.

C. Limitations and Further Research

This study has several limitations. First, the study was conducted in only three industries (baby goods, shoes and tires) and author only collected data from 57 online stores. However, all the online stores owned by four merchants' groups (Babyaisle, Eobuwie, Oponeo and Babymarkt) were the subject of the study. The author acknowledges, however, that this sample cannot adequately represent the entire cross-border e-commerce industry as it does not reflect any online store outside the EU. To make the conclusions more convincing, data from more cross-border e-commerce need to be collected in the future. Second, observations were conducted only for the three companies based in Poland and one originating from Germany. These observations, therefore, do not reflect online cross-border e-commerce in other European countries. Data reflecting more European countries need to be collected to further investigate the role of retailers' country origin. Third, the load time may vary according to time-of-day, and also period of the year. Fourth, although each online store was observed in terms of the same DNS lookup time, connect time and time-to-first-byte, there are still some unobservable factors across an online store that might have influence for overall speed. Further studies will need to retrieve more data to address this issue.

APPENDIX

Appendix contains 57 domains from four sets with lookup time, connect time, TTFB time and current IP address.

Online store	Lookup time (s)	Connect time (s)	TTFB (s)	IP
babyaisle.it	0.005	0.053	1.685	176.119.53.127
babyaisle.es	0.004	0.055	1.488	176.119.53.1
babyaisle.cz	0.005	0.057	1.462	176.119.53.127
babyaisle.dk	0.015	0.062	1.390	104.25.247.100
babyaisle.de	0.013	0.080	1.542	104.25.138.110
babyland.pl	0.128	0.187	1.508	104.25.180.101
babyaisle.fr	0.133	0.192	1.324	104.27.168.56
babyaisle.eu	0.137	0.199	1.474	104.31.83.41
eskor.se	0.004	0.053	0.370	104.16.227.90
eavalynne.lt	0.004	0.054	0.312	104.17.209.100
zapatos.es	0.005	0.059	0.318	104.18.215.17
ecipo.hu	0.015	0.065	0.325	104.16.86.10
eobuwie.com.pl	0.019	0.076	0.326	104.17.26.2
epapoutsia.gr	0.014	0.079	0.323	104.16.187.97
chaussures.fr	0.133	0.181	0.446	104.17.187.60
epantofi.ro	0.133	0.186	0.515	104.16.135.30
eschuhe.ch	0.132	0.187	0.450	104.16.124.11
eobuv.com.ua	0.132	0.187	0.445	104.18.212.19
efootwear.eu	0.135	0.188	0.463	104.18.236.59
eobuv.sk	0.131	0.188	0.431	104.18.72.16
eobuv.cz	0.130	0.189	0.438	104.16.86.67
escarpe.it	0.131	0.190	0.440	104.16.158.98
obuvki.bg	0.141	0.190	0.453	104.17.44.78
eobuv.com	0.134	0.194	0.461	104.18.69.27
oponeo.fr	0.005	0.059	0.848	91.206.7.197
oponeo.cz	0.004	0.061	0.976	91.206.7.194
oponeo.pl	0.005	0.064	0.471	91.206.7.26
oponeo.hu	0.005	0.065	0.770	91.206.7.199
oponeo.com	0.005	0.067	0.364	91.206.7.121
pneus-oponeo.be	0.005	0.068	0.765	91.206.7.147
oponeo.ie	0.013	0.068	0.889	91.206.7.196
oponeo.ch	0.004	0.068	0.943	91.206.7.19
oponeo.at	0.013	0.070	0.958	91.206.7.231
oponeo.com.tr	0.016	0.071	0.570	91.206.7.21
banden-oponeo.be	0.005	0.071	1.036	91.206.7.177
oponeo.es	0.013	0.072	0.629	91.206.7.187
oponeo.sk	0.013	0.072	0.765	91.206.7.142
oponeo.de	0.013	0.073	0.753	91.206.7.182
oponeo.co.uk	0.014	0.074	0.443	91.206.7.189
pneus-oponeo.ch	0.015	0.081	0.693	91.206.7.100
oponeo.nl	0.013	0.084	0.758	91.206.7.198
oponeo.it	0.037	0.094	0.486	91.206.7.188
pinkorblue.cz	0.006	0.071	0.509	37.49.153.153
baby-markt.ch	0.004	0.073	0.428	37.49.153.153
pinkorblue.be	0.005	0.076	0.455	37.49.153.153
rosaoazul.es	0.015	0.082	0.456	37.49.153.153
pinkorblue.dk	0.015	0.105	0.412	37.49.153.153
baby-markt.at	0.005	0.127	0.416	37.49.153.153
pinkorblue.se	0.130	0.197	0.608	37.49.153.153
pinkorblue.fi	0.130	0.199	0.592	37.49.153.153
baby-markt.com	0.132	0.200	0.613	37.49.153.153
pinkorblue.nl	0.134	0.201	0.574	37.49.153.153
pinkorblue.no	0.130	0.204	0.658	37.49.153.153
pinkorblue.it	0.135	0.206	0.563	37.49.153.153
pinkorblue.pl	0.134	0.208	0.540	37.49.153.153
roseoubleu.fr	0.264	0.366	0.718	37.49.153.153
babymarkt.de	0.522	0.638	0.955	37.49.153.153

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