[[1]](#footnote-1)

Analysis of the Lighting Network(2021)

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*Abstract*— **Bitcoin is the most established cryptocurrency in the market but is still rapidly developing in structure. The original decentralized transaction system now has added second level protocols to facilitate larger volumes of transactions with faster clearing times and lower fees. In this emerging second level transaction marketplace, there are low barriers to entry and opportunities to optimize structure and revenue as a transaction clearing house (node). Our goal is to analyze publicly available data on the market, set up our own node to process transactions, and study methods of optimizing our node structure and fee rates. Beyond the timeline of this initial project and as we collect private data on our node transactions, we aim to build models predicting total revenue as a response to our fee rates and liquidity. The models optimum setup would then be tested on our own node and iteratively updated with new data. Phase 2 of this project could potentially be evaluated as a capstone project.**

*Index Terms*— Bitcoin, Blockchain, Cryptography, Lightning Network, Network Analysis, Optimization, Payments,

# INTRODUCTION

B

itcoin is a digital cryptocurrency created in 2009. Unlike fiat currency, bitcoin is created, distributed, traded, and stored with the use of a decentralized ledger system, known as a blockchain. It has lower transaction fees than traditional online payments using centralized banks and government issued currencies.

Reference: <https://www.investopedia.com/terms/b/bitcoin.asp>

# On Chain Vs Off Chain Transactions

Bitcoin uses a blockchain as a ledger to record all transactions. All bitcoin in existence can be found somewhere on the blockchain. All Bitcoin transactions recorded on the blockchain are considered **on-chain transactions** and the ledger is available to the public. Bitcoin is locked in an address, and, using the private key corresponding to that address, you can sign a transaction sending this bitcoin to a new address. All on-chain transactions must pay a transaction fee in order to be included in a block. The higher the fee, the faster the transaction will be confirmed. On-chain transactions are highly secure and reliable, however transaction fees are rising based on demand and the time to confirm and clear a transaction can take 10 minutes to multiple hours. Bitcoin blocks can only hold a certain number of transactions so this method of transaction lacks scalability.

## Off Chain transactions

Off-chain transactions occur through a private peer-to-peer network where a channel is set up to make many transactions between merchant and/or individual pairs. When the parties have concluded a group of transactions, similar to a tab, the net transfer amount is recorded as a single on-chain transaction and becomes part of the public blockchain ledger. The benefits are lower transaction fees, faster (near instant) confirmation and clearing of transactions and improved scalability for large numbers of transactions. The tradeoffs are higher risk private transactions, capital to meet liquidity requirements, and capacity limits on channels which limit large transactions.\*

## Blocksize Dilemma

The reader at this point may wonder why not increase the blocksize. Doing so would increase the throughput of the system and eliminate the need for a second layer payment network. The answer is complicated. Bitcoin protocol is not controlled by anyone person or body. The Bitcoin miners are one body within the network that assert influence. The miners solve a hash problem to assemble a new block. This earns them six Bitcoins per block and processes transactions with the remaining space on the block. Each block has a theoretical maximum size of 4 megabytes but a more realistic maximum size of 2 megabytes. User who run an active node assert another vector of influence. Nodes validate transactions and blocks and accepts transactions from other nodes to support the network. Nodes check each transaction by verifying the rules of the Bitcoin Protocol are met. If a transactions breaks the rules the nodes want accept it as a valid transactions. This prevents miner’s from creating a Bitcoins out of thin air. Or unilaterally changing the Blocksize limit. Bitcoin Core developers are the third body within the network that exert influence. They test the protocol, debug and support miners and nodes.

Thus changing the protocol requires a large consensus of compute power on Bitcoin’s network from miner’s and nodes, that are supported by developers. Such a change was proposed in 2017. “Big Blockers” arguing in favor of increasing the artificial block limit. They argued doing so would benefit the network by increasing throughput. “Small Blockers” resisted the change. Their argument was that large blocksizes would inhibit ordinary individuals from running a nodes. This they argued would centralize the network to a few nodes that could handle such dramatic increase in compute and bandwidth requirements.

August of 2017 a contingent of big blockers hard-forked the protocol and started Bitcoin Cash. This created a non-backwards compatible implementation protocol that would enable bitcoin’s use as a medium for daily exchange. Less than a year later Bitcoin Cash underwent a hard-fork that saw the creation of Bitcoin SV. Both of these new protocols lacked the general support from developers, miners and nodes.

During the same period work on the lightning network continued. Second layer payment network gained wider adoption. The market for Bitcoin has increased and Bitcoin hard forks and trading at less than 1% of Bitcoin’s value. Seemingly the small blockers won that skirmish. Consensus for achieving scalability through a second layer payment network has won out, for now.

# What is the Lightning Network

Bitcoin Lightning Network is a second-layer protocol designed to enable off-chain Bitcoin transactions. It aims at breaking the trade-off between block size and centralisation by processing most of the transactions off-chain: it is a 'layer 2' protocol that can operate on top of Blockchain-based cryptocurrencies such as Bitcoin.  Because they are not recorded on the blockchain, and thus require no mining, Lightning payments are extremely fast and cheap. Unlike the Bitcoin network, Lightning transactions are not publicly broadcast and instead, individual Lightning nodes transact with one another privately.

For example a transaction from party A to party D is not direct and channel is opened Party A 🡪 Node B 🡪 Node C 🡪 Party D. Each node comprising the channel earn a fee for each transaction run through the channel in each direction. When all transactions are complete a single net on-chain transaction is made to the public ledger. The combination of small node transaction fees and the final larger on-chain fee result in a lower fee per transaction and transactions clear much faster.

The network we consider has a fixed number of nodes *N* – corresponding to all Bitcoin users that may decide to switch to the LN – and is *sparse*, i.e. the number *M* of edges is *M* ≪ *N*2. If we consider node *i* and *j* having fitness *xi* and *xj* respectively, a LN channel, i.e. an edge between them, is added with probability

Text

Description automatically generated

I In a payment channel, cryptographic protections are used to ensure that channel updates in both directions are executed atomically, i.e., either both or neither of them are performed [13]. In addition, incentive-based protections are also implemented to prevent users from stealing funds in a channel, e.g., by committing a revoked state. Similar techniques allow payment routing for longer paths. Furthermore, payment router intermediaries are financially motivated to relay payments as they are entitled to claim transaction fees after each successfully routed payment. LN as a PCN consists of nodes representing users and undirected, weighted edges representing payment channels. Users can open and close bidirectional payment channels between each other and route payments through these connections. Therefore, LN can be modeled as an undirected, weighted multigraph since nodes can have multiple channels between each other. The weights on the edges correspond to the capacity of the payment channels. In LN only capacities of payment channels are known publicly, individual balances are kept secret. This is because if individual balances are known, balance updates would reveal successful transactions, hence preventing transaction privacy

# Collecting and analyzing data

Throughout our work we tried several methods of collecting Data. BTCPayServer is an open source project that allows online vendors to easily accept and generate invoices. MyNode is a private company that offers licensed software compatible with market available hardware to run a Bitcoin Node. Simulated data from Ferenc Beres Lightning Network Simulation. Once collected the collection plan called for storing the data in MongoDB.

# Issues with Data colelction

BTCPay Server is optimized for web based vendors. The software stack is easy to run and operate a node but our team found it difficult to off load this data. MyNode is a promising application that allowed the team to take physical control of the node and data storage but ran into inssues of slow Bitcoin synchronization. Whereas with BTCPay Server the team made us of distributed compute technologies to shorten the synchronization time. MyNode synchronization of the blockchain network is much slower. The delay in gathering data through this method meant moving on to analysis phase without the MyNode data.

Ferenc Beres Lighning Node Simulator providing the team with a simulated lighnthing network traffic data. It used snapshots of the network collected from a period of from 2018 through 2019. Using the Lightning network simulator we accepted a few strong assumptions. First, that data from that time period is still relevant today. Fixed payments amounts is another strong assumption. However, various distributions such as Poisson on Pareto greatly increases the complexity of the experimentation. Though because payments are not public these distributions could not be empirically validated.

Thus at the onset of each simulation ransomized capacity between channel and endpoints was used. word “data” is plural, not singular. For example, if Γ is the total capacity of the channel between nodes u and v, we let 0 ≤ γ(uv) ≤ Γ and 0 ≤ γ(vu) ≤ Γ denote the maximum value in satoshis, which can be routed from u to v and vice versa. Both γ(uv) and γ(vu) change after each transaction that uses this channel while maintaining γ(uv) + γ(vu) = Γ at all times.. The subscript for the permeability of vacuum µ0 is zero, not a lowercase letter “o.” The term for residual magnetization is “remanence”; the adjective is “remanent”; do not write “remnance” or “remnant.” Use the word “micrometer” instead of “micron.” A graph within a graph is an “inset,” not an “insert.” The word “alternatively” is preferred to the word “alternately” (unless you really mean something that alternates). Use the word “whereas” instead of “while” (unless you are referring to simultaneous events). Do not use the word “essentially” to mean “approximately” or “effectively.” Do not use the word “issue” as a euphemism for “problem.” When compositions are not specified, separate chemical symbols by en-dashes; for example, “NiMn” indicates the intermetallic compound Ni0.5Mn0.5 whereas “Ni–Mn” indicates an alloy of some composition NixMn1-x.

Be aware of the different meanings of the homophones “affect” (usually a verb) and “effect” (usually a noun), “complement” and “compliment,” “discreet” and “discrete,” “principal” (e.g., “principal investigator”) and “principle” (e.g., “principle of measurement”). Do not confuse “imply” and “infer.”

Prefixes such as “non,” “sub,” “micro,” “multi,” and “ultra” are not independent words; they should be joined to the words they modify, usually without a hyphen. There is no period after the “et” in the Latin abbreviation “*et al.*” (it is also italicized). The abbreviation “i.e.,” means “that is,” and the abbreviation “e.g.,” means “for example” (these abbreviations are not italicized).

A general IEEE styleguide is available at <http://www.ieee.org/web/publications/authors/transjnl/index.html>



Fig. 1. Magnetization as a function of applied field. Note that “Fig.” is abbreviated. There is a period after the figure number, followed by two spaces. It is good practice to explain the significance of the figure in the caption.

TABLE I

Units for Magnetic Properties

|  |  |  |
| --- | --- | --- |
| Symbol | Quantity | Conversion from Gaussian and  CGS EMU to SI a |
| Φ | magnetic flux | 1 Mx → 10−8 Wb = 10−8 V·s |
| *B* | magnetic flux density,  magnetic induction | 1 G → 10−4 T = 10−4 Wb/m2 |
| *H* | magnetic field strength | 1 Oe → 103/(4π) A/m |
| *m* | magnetic moment | 1 erg/G = 1 emu  → 10−3 A·m2 = 10−3 J/T |
| *M* | magnetization | 1 erg/(G·cm3) = 1 emu/cm3  → 103 A/m |
| 4π*M* | magnetization | 1 G → 103/(4π) A/m |
| σ | specific magnetization | 1 erg/(G·g) = 1 emu/g → 1 A·m2/kg |
| *j* | magnetic dipole  moment | 1 erg/G = 1 emu  → 4π × 10−10 Wb·m |
| *J* | magnetic polarization | 1 erg/(G·cm3) = 1 emu/cm3  → 4π × 10−4 T |
| χ*,* κ | susceptibility | 1 → 4π |
| χρ | mass susceptibility | 1 cm3/g → 4π × 10−3 m3/kg |
| μ | permeability | 1 → 4π × 10−7 H/m  = 4π × 10−7 Wb/(A·m) |
| μr | relative permeability | μ → μr |
| *w, W* | energy density | 1 erg/cm3 → 10−1 J/m3 |
| *N, D* | demagnetizing factor | 1 → 1/(4π) |

Vertical lines are optional in tables. Statements that serve as captions for the entire table do not need footnote letters.

aGaussian units are the same as cg emu for magnetostatics; Mx = maxwell, G = gauss, Oe = oersted; Wb = weber, V = volt, s = second, T = tesla, m = meter, A = ampere, J = joule, kg = kilogram, H = henry.

# Guidelines for Graphics Preparation and Submission

## Types of Graphics

The following list outlines the different types of graphics published in IEEE journals. They are categorized based on their construction, and use of color / shades of gray:

### *Color/Grayscale figures*

### Figures that are meant to appear in color, or shades of black/gray. Such figures may include photographs, illustrations, multicolor graphs, and flowcharts.

### *Lineart figures*

### Figures that are composed of only black lines and shapes. These figures should have no shades or half-tones of gray. Only black and white.

### *Author photos*

### Head and shoulders shots of authors which appear at the end of our papers.

### *Tables* Data charts which are typically black and white, but sometimes include color.

## Multipart figures

Figures compiled of more than one sub-figure presented side-by-side, or stacked. If a multipart figure is made up of multiple figure types (one part is lineart, and another is grayscale or color) the figure should meet the stricter guidelines.

## File Formats For Graphics

Format and save your graphics using a suitable graphics processing program that will allow you to create the images as PostScript (PS), Encapsulated PostScript (.EPS), Tagged Image File Format (.TIFF), Portable Document Format (.PDF), or Portable Network Graphics (.PNG) sizes them, and adjusts the resolution settings. If you created your source files in one of the following programs you will be able to submit the graphics without converting to a PS, EPS, TIFF, PDF, or PNG file: Microsoft Word, Microsoft PowerPoint, or Microsoft Excel. Though it is not required, it is recommended that these files be saved in PDF format rather than DOC, XLS, or PPT. Doing so will protect your figures from common font and arrow stroke issues that occur when working on the files across multiple platforms. When submitting your final paper, your graphics should all be submitted individually in one of these formats along with the manuscript.

## Sizing of Graphics

Most charts, graphs, and tables are one column wide (3.5 inches / 88 millimeters / 21 picas) or page wide (7.16 inches / 181 millimeters / 43 picas). The maximum depth a graphic can be is 8.5 inches (216 millimeters / 54 picas). When choosing the depth of a graphic, please allow space for a caption. Figures can be sized between column and page widths if the author chooses, however it is recommended that figures are not sized less than column width unless when necessary.

There is currently one publication with column measurements that don’t coincide with those listed above. Proceedings of the IEEE has a column measurement of 3.25 inches (82.5 millimeters / 19.5 picas).

The final printed size of author photographs is exactly   
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## Resolution

The proper resolution of your figures will depend on the type of figure it is as defined in the “Types of Figures” section. Author photographs, color, and grayscale figures should be at least 300dpi. Lineart, including tables should be a minimum of 600dpi.

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While IEEE does accept, and even recommends that authors submit artwork in vector format, it is our policy is to rasterize all figures for publication. This is done in order to preserve the figures’ integrity across multiple computer platforms.

## Color Space

The term color space refers to the entire sum of colors that can be represented within the said medium. For our purposes, the three main color spaces are Grayscale, RGB (red/green/blue) and CMYK (cyan/magenta/yellow/black). RGB is generally used with on-screen graphics, whereas CMYK is used for printing purposes.

All color figures should be generated in RGB or CMYK color space. Grayscale images should be submitted in Grayscale color space. Line art may be provided in grayscale OR bitmap colorspace. Note that “bitmap colorspace” and “bitmap file format” are not the same thing. When bitmap color space is selected, .TIF/.TIFF is the recommended file format.

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When preparing your graphics IEEE suggests that you use of one of the following Open Type fonts: Times New Roman, Helvetica, Arial, Cambria, and Symbol. If you are supplying EPS, PS, or PDF files all fonts must be embedded. Some fonts may only be native to your operating system; without the fonts embedded, parts of the graphic may be distorted or missing.

A safe option when finalizing your figures is to strip out the fonts before you save the files, creating “outline” type. This converts fonts to artwork what will appear uniformly on any screen.

## Using Labels Within Figures

### Figure Axis labels

Figure axis labels are often a source of confusion. Use words rather than symbols. As an example, write the quantity “Magnetization,” or “Magnetization *M*,” not just “*M*.” Put units in parentheses. Do not label axes only with units. As in Fig. 1, for example, write “Magnetization (A/m)” or “Magnetization (Am−1),” not just “A/m.” Do not label axes with a ratio of quantities and units. For example, write “Temperature (K),” not “Temperature/K.”

Multipliers can be especially confusing. Write “Magnetization (kA/m)” or “Magnetization (103 A/m).” Do not write “Magnetization (A/m) × 1000” because the reader would not know whether the top axis label in Fig. 1 meant 16000 A/m or 0.016 A/m. Figure labels should be legible, approximately 8 to 10 point type.

### Subfigure Labels in Multipart Figures and Tables

Multipart figures should be combined and labeled before final submission. Labels should appear centered below each subfigure in 8 point Times New Roman font in the format of (a) (b) (c).

## File Naming

Figures (line artwork or photographs) should be named starting with the first 5 letters of the author’s last name. The next characters in the filename should be the number that represents the sequential location of this image in your article. For example, in author “Anderson’s” paper, the first three figures would be named ander1.tif, ander2.tif, and ander3.ps.

Tables should contain only the body of the table (not the caption) and should be named similarly to figures, except that ‘.t’ is inserted in-between the author’s name and the table number. For example, author Anderson’s first three tables would be named ander.t1.tif, ander.t2.ps, ander.t3.eps.

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If two authors or more have the same last name, their first initial(s) can be substituted for the fifth, fourth, third... letters of their surname until the degree where there is differentiation. For example, two authors Michael and Monica Oppenheimer’s photos would be named oppmi.tif, and oppmo.eps.

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# Conclusion

## A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

Appendix

Appendixes, if needed, appear before the acknowledgment.

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The preferred spelling of the word “acknowledgment” in American English is without an “e” after the “g.” Use the singular heading even if you have many acknowledgments. Avoid expressions such as “One of us (S.B.A.) would like to thank ... .” Instead, write “F. A. Author thanks ... .” In most cases, sponsor and financial support acknowledgments are placed in the unnumbered footnote on the first page, not here.

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References need not be cited in text. When they are, number citations on the line, in square brackets inside the punctuation. Multiple references are each numbered with separate brackets. When citing a section in a book, please give the relevant page numbers. In text, refer simply to the reference number. Do not use “Ref.” or “reference” except at the beginning of a sentence: “Reference [3] shows ... .” Please do not use automatic endnotes in *Word*, rather, type the reference list at the end of the paper using the “References” style.

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Number footnotes separately in superscripts (Insert | Footnote).[[2]](#footnote-2) Place the actual footnote at the bottom of the column in which it is cited; do not put footnotes in the reference list (endnotes). Use letters for table footnotes (see Table I).

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References

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1. J. K. Author, “Title of chapter in the book,” in *Title of His Published Book, x*th ed. City of Publisher, Country if not
2. USA: Abbrev. of Publisher, year, ch. *x*, sec. *x*, pp. *xxx–xxx.*

*Examples:*

1. G. O. Young, “Synthetic structure of industrial plastics,” in *Plastics,* 2nd ed., vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 15–64.
2. W.-K. Chen, *Linear Networks and Systems.* Belmont, CA: Wadsworth, 1993, pp. 123–135.

*Basic format for periodicals:*

1. J. K. Author, “Name of paper,” *Abbrev. Title of Periodical*, vol. *x,* no. *x,* pp*. xxx-xxx,* Abbrev. Month, year.

*Examples:*

1. J. U. Duncombe, “Infrared navigation—Part I: An assessment   
   of feasibility,” *IEEE Trans. Electron Devices*, vol. ED-11, no. 1, pp. 34–39, Jan. 1959.
2. E. P. Wigner, “Theory of traveling-wave optical laser,” *Phys. Rev*.,   
   vol. 134, pp. A635–A646, Dec. 1965.
3. E. H. Miller, “A note on reflector arrays,” *IEEE Trans. Antennas Propagat*., to be published.

*Basic format for reports:*

1. J. K. Author, “Title of report,” Abbrev. Name of Co., City of Co., Abbrev. State, Rep. *xxx*, year.

*Examples:*

1. E. E. Reber, R. L. Michell, and C. J. Carter, “Oxygen absorption in the earth’s atmosphere,” Aerospace Corp., Los Angeles, CA, Tech. Rep. TR-0200 (4230-46)-3, Nov. 1988.
2. J. H. Davis and J. R. Cogdell, “Calibration program for the 16-foot antenna,” Elect. Eng. Res. Lab., Univ. Texas, Austin, Tech. Memo. NGL-006-69-3, Nov. 15, 1987.

*Basic format for handbooks:*

1. *Name of Manual/Handbook*, *x* ed., Abbrev. Name of Co., City of Co., Abbrev. State, year, pp. *xxx-xxx.*

*Examples:*

1. *Transmission Systems for Communications*, 3rd ed., Western Electric Co., Winston-Salem, NC, 1985, pp. 44–60.
2. *Motorola Semiconductor Data Manual*, Motorola Semiconductor Products Inc., Phoenix, AZ, 1989.

*Basic format for books (when available online):*

1. Author. (year, month day). *Title.* (edition) [Type of medium]. *volume (issue).* Available: site/path/file

*Example:*

1. J. Jones. (1991, May 10). *Networks.* (2nd ed.) [Online]. Available: [http://www.atm.com](http://www.atm.com/)

*Basic format for journals (when available online):*

1. Author. (year, month). Title. *Journal.* [Type of medium]. *volume (issue),* pages. Available: site/path/file

*Example:*

1. R. J. Vidmar. (1992, Aug.). On the use of atmospheric plasmas as electromagnetic reflectors. *IEEE Trans. Plasma Sci.* [Online]. *21(3),* pp. 876–880. Available:<http://www.halcyon.com/pub/journals/21ps03-vidmar>

*Basic format for papers presented at conferences (when available online):*

1. Author. (year, month). Title. Presented at Conference title. [Type of Medium]. Available: site/path/file

*Example:*

1. PROCESS Corp., MA. Intranets: Internet technologies deployed behind the firewall for corporate productivity. Presented at   
   INET96 Annual Meeting. [Online]. Available: <http://home.process.com/Intranets/wp2.htp>

*Basic format for reports and handbooks (when available online):*

1. Author. (year, month). Title. Comp an y . C ity, State or Country. [Type of Medium]. Available: site/path/file

*Example:*

1. S. L. Tall een. (1996 , Apr . ). The In t r an et Archi -tecture: M a nagi ng i n f o rm at i on i n t h e ne w paradigm. Amdahl Corp., CA. [Online]. Available:<http://www.amdahl.com/doc/products/bsg/intra/infra/html>

*Basic format for computer programs and electronic documents (when available online):* ISO recommends that capitalization follow the accepted practice for the language or script in which the information is given.

*Example:*

1. A. Harriman. (1993, June). Compendium of genealogical software. *Humanist.* [Online]. Available e-mail: [HUMANIST@NYVM.ORG](mailto:HUMANIST@NYVM.ORG) Message: get GENEALOGY REPORT

*Basic format for patents (when available online):*

1. Name of the invention, by inventor’s name. (year, month day). *Patent Number* [Type of medium]. Available: site/path/file

*Example:*

1. Musical toothbrush with adjustable neck and mirror, by L.M.R. Brooks. (1992, May 19). *Patent D 326 189*

[Online]. Available: NEXIS Library: LEXPAT File: DESIGN

*Basic format for conference proceedings (published):*

1. J. K. Author, “Title of paper,” in *Abbreviated Name of Conf.*, City of Conf., Abbrev. State (if given), year, pp. *xxxxxx.*

*Example:*

1. D. B. Payne and J. R. Stern, “Wavelength-switched pas- sively coupled single-mode optical network,” in *Proc. IOOC-ECOC,* 1985,   
   pp. 585–590.

*Example for papers presented at conferences (unpublished):*

1. D. Ebehard and E. Voges, “Digital single sideband detection for interferometric sensors,” presented at the 2nd Int. Conf. Optical Fiber Sensors, Stuttgart, Germany, Jan. 2-5, 1984.

*Basic format for patents:*

1. J. K. Author, “Title of patent,” U.S. Patent *x xxx xxx*, Abbrev. Month, day, year.

*Example:*

1. G. Brandli and M. Dick, “Alternating current fed power supply,”   
   U.S. Patent 4 084 217, Nov. 4, 1978.

*Basic format**for theses (M.S.) and dissertations (Ph.D.):*

1. J. K. Author, “Title of thesis,” M.S. thesis, Abbrev. Dept., Abbrev. Univ., City of Univ., Abbrev. State, year.
2. J. K. Author, “Title of dissertation,” Ph.D. dissertation, Abbrev. Dept., Abbrev. Univ., City of Univ., Abbrev. State, year.

*Examples:*

1. J. O. Williams, “Narrow-band analyzer,” Ph.D. dissertation, Dept. Elect. Eng., Harvard Univ., Cambridge, MA, 1993.
2. N. Kawasaki, “Parametric study of thermal and chemical nonequilibrium nozzle flow,” M.S. thesis, Dept. Electron. Eng., Osaka Univ., Osaka, Japan, 1993.

*Basic format for the most common types of unpublished references:*

1. J. K. Author, private communication, Abbrev. Month, year.
2. J. K. Author, “Title of paper,” unpublished.
3. J. K. Author, “Title of paper,” to be published.

*Examples:*

1. A. Harrison, private communication, May 1995.
2. B. Smith, “An approach to graphs of linear forms,” unpublished.
3. A. Brahms, “Representation error for real numbers in binary computer arithmetic,” IEEE Computer Group Repository, Paper R-67-85.

*Basic format for standards:*

1. *Title of Standard*, Standard number, date.

*Examples:*

1. IEEE Criteria for Class IE Electric Systems, IEEE Standard 308, 1969.
2. Letter Symbols for Quantities, ANSI Standard Y10.5-1968.

1. “Bitcoin summary is supported by the Investopedia website. Reference: <https://www.investopedia.com/terms/b/bitcoin.asp>

   . “On Chain Vs off chain transactions information is supported by the following Reference: <https://river.com/learn/on-chain-vs-off-chain-bitcoin-transactions/>

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2. It is recommended that footnotes be avoided (except for the unnumbered footnote with the receipt date on the first page). Instead, try to integrate the footnote information into the text. [↑](#footnote-ref-2)