

ECC implementation on Nano FPGAs. The proposed ECC cryptoprocessor was modeled using VHDL and synthesized on Actel IGLOO AGLN250V2-VQFP100 Nano FPGA. The synthesis results showed that the targeted Nano FPGA could not exceed the values of $m \leq 11$ bits. This is because of the limited number of resources available on Nano FPGAs. The area result opened a new challenging opportunity for future Nano FPGAs to satisfy the needs of critical portable applications and resource-constrained devices, such as Wireless Sensor Network (WSN).

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8. References

- [1] N. Koblitz, Elliptic curve cryptosystems. *Math. Comput.*, Vol. 48, No. 177, pp. 203-209, 1987.
- [2] V.S. Miller, "Use of elliptic curves in cryptography", in *Proc. of the Advances in Cryptology CRYPTO '85*, Springer-Verlag, LNCS 218, pp: 417-426, 1986.
- [3] R. Rivest, A. Shamir and L. Adleman, "A method for obtaining digital signatures and public key cryptosystems". *Commun. ACM*, Vol. 21, No.2, pp. 120-126, 1978.
- [4] A. Menezes, "Elliptic Curve Public Key Cryptosystems", 1st edition, Kluwer Academic Publishers, 1993.
- [5] D. Hankerson, A. Menezes, and S. Vanstone, "Guide to Elliptic Curve Cryptography". 1st edition, Springer, 2004.
- [6] C. Paar and J. Pelzl, "Understanding Cryptography: A Textbook for Students and Practitioners". 1st edition, Springer-Verlag, Berlin Heidelberg, 2010.
- [7] T. ElGamal, "A Public-Key Cryptosystem and a Signature Scheme Based on Discrete Logarithms. *Advances in Cryptology*", in *Proc. of CRYPTO 84*, August 19-22, Springer Verlag, pp. 10-18, 1985.
- [8] D. Hankerson, J.L.Hernandez and A. Menezes, "Software Implementation Of Elliptic Curve Cryptography Over Binary fields. *Cryptographic hardware and Embedded Systems*", CHES 2000, LNCS 1965, Springer-Verlag, 1-24, 2000.
- [9] N. Gura, A. Patel, A. S. Wander, H. Eberle, and S. Chang Shantz, "Comparing elliptic curve cryptography and RSA on 8-bit CPUs", in *Cryptographic Hardware and Embedded Systems — CHES 2004*, vol. 3156 of *Lecture Notes in Computer Science*, pp. 119-132. Springer Verlag, 2004.
- [10] S. Khajuria and H. Tange, "Implementation of diffie-Hellman key exchange on wireless sensor using elliptic curve cryptography", in *Proc. 1st International Conference on Wireless Communication, Vehicular Technology, Information Theory and Aerospace and Electronic Systems Technology (Wireless VITAE '09)*, pp. 772-776, May 2009.
- [11] J. Lutz and A. Hasan, "High performance FPGA based elliptic curve cryptographic co-processor," in *Proc. Int. Conf. Inf. Technol.: Coding Comput. (ITCC)*, 2004, p. 486.
- [12] G. Meurice de Dormale and J.-J. Quisquater, High-speed hardware implementations of Elliptic Curve Cryptography: A survey. *Journal of Systems Architecture: the EUROMICRO Journal*, Volume 53, Issue 2-3, pp. 72 – 84, February, 2007.
- [13] K. Jarvinen and J. Skytta, On Parallelization of High-Speed Processors for Elliptic Curve Cryptography, *IEEE Trans. on VLSI*, Vol. 16, Issue 9, pp. 1162 – 1175, 2008.
- [14] B. Ansari and M. A. Hasan, "High-Performance Architecture of Elliptic Curve Scalar Multiplication", *IEEE Trans. on Computers*, Vol.57, No.11, pp. 1443-1453, 2008.
- [15] Kimmo Järvinen, "Optimized FPGA-based elliptic curve cryptography processor for high-speed applications", *Integration, the VLSI Journal*, Volume 44, Issue 4, pp. 270-279, 2011.
- [16] Actel IGLOO Nano FPGA Data Sheet, available from: http://www.actel.com/documents/IGLOO_nano_DS.pdf
- [17] R. Lidl, and H. Niederreiter, "Introduction to finite fields and their applications", Cambridge University Press, Cambridge, UK, 2nd edition, 1994.
- [18] R. C. MULLIN and R. M. WILSON, "Optimal normal bases in $GF(p^n)$ ", *Discrete Appl. Math.*, 22, pp. 149-161, 1988/1989.
- [19] H. Cohen, G. Frey, R.M. Avanzi, C. Doche, T. Lange, K. Nguyen and F. Vercauteren, "Handbook of Elliptic and Hyperelliptic Curve Cryptography". *Discrete Mathematics and Its Applications*, Vol. 34, Chapman and Hall, CRC, USA, 2005.
- [20] J.L. Massey and J.K. Omura, "Computational Method and Apparatus for Finite Field Arithmetic," US Patent No. 4,587,627, 1986.
- [21] T. F. Al-Somani and A. Amin. "Hardware implementations of $GF(2^m)$ arithmetic using normal basis", *J. Appl. Sci.*, Vol. 6, Issue 6, pp. 1362-1372, 2006.
- [22] T. Itoh and S. Tsujii. "A Fast Algorithm for Computing Multiplicative Inverses in $GF(2^m)$ Using Normal Bases", *Information and Computation*, Vol. 78, pp. 171-177, 1988.
- [23] D. Estrin, R. Govindan, J. Heidemann, and S. Kumar, "Next Century Challenges: Scalable Coordination in Sensor Networks", in *Mobile Computing and Networking (MobiCom'99)*, Seattle, WA USA (1999) 263-270.
- [24] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam and E. Cayirci, "Wireless Sensor Networks: a survey", *Computer Networks*, Volume 38, Issue 4, 15 March 2002, Pages 393-422.